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WATER RESOURCES ACTIVITIES IN THE UNITED STATES. ESTIMATED WATER REQUIREMENTS FOR AGRICULTURAL PURPOSES AND THEIR EFFECTS ON WATER SUPPLIES

Select Committee on National Water Resources, U. S. Senate

December 1959

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WATER RESOURCES ACTIVITIES IN THE UNITED STATES

ESTIMATED WATER REQUIREMENTS FOR AGRICULTURAL PURPOSES AND THEIR EFFECTS ON WATER SUPPLIES

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS
FIRST SESSION

DECEMBER 1959

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STATEMENT BY THE CHAIRMAN

DECEMBER 29, 1959.

To the Members of the Select Committee on National Water Resources:

In addition to the direct use of water for agricultural production there are a number of other programs for the conservation and development of our agricultural land and water resources which may have significant effects on our national water resources. These include the runoff and waterflow retardation and soil erosion prevention programs, the small watershed improvement program, and other programs for the improvement of land and water use for agricultural purposes for which the Department of Agriculture is the Federal agency having primary responsibility.

As a means of helping the Select Committee on National Water Resources to comply with the directives contained in Senate Resolution 48, I asked the Department of Agriculture to prepare a report for the committee, as to how the Nation's needs for these services and activities can best be met and to estimate the water requirements resulting from such programs between now and 1980 and looking on toward the year 2000. The report prepared by the Department considers the effect of programs for land use and treatment, water control structures, and future irrigation increases projected in Committee Print No. 12, on onsite and downstream water yields. All the estimates contained in the report are based on medium population levels for 1980 and 2000, which were furnished the Department by the committee staff.

The report estimates that present land treatment programs have been put into effect on 18 percent of our cropland, pastures, and woodlands; that this will increase to 32 percent by 1980, and 52 percent by the year 2000 in accordance with anticipated needs. An increase in the estimated total number of structural measures for the control of water on watersheds is projected from 938,000 in 1959 to over 2 million in 1980, and to over 2½ million in the year 2000. The land-treatment programs are estimated to decrease downstream water yield in 1980 by about 1¼ million acre-feet and by about 3.1 million acre-feet in the year 2000. The use of water at site will be substantially greater. The structural measures are estimated to decrease downstream water supplies in 1980 by 3¼ million acre-feet and by 4⅔ million acre-feet in the year 2000. Again, water used at site will be greater. These programs thus will deplete downstream flows by 4½ million acre-feet in 1980, and by 7.8 million acre-feet in 2000. These amounts are shown to be small in comparison to the requirements of irrigated agriculture and the Department indicates that by increased efficiency in irrigation, as much as 50 million acre-feet of water annually can be saved.

This report should be of great interest to you, to other Members of the Senate, and others interested in finding solutions to the Nation's water resources problems. Accordingly, I am having the report printed as one of our committee prints dealing with all aspects of water resources activities in the United States.

Because of the limited time available and the unavailability of material on Alaska and Hawaii, these States are not covered in the enclosed report.

ROB'T S. KERR, *Chairman.*

COMMUNICATIONS

JULY 6, 1959.

Hon. EZRA TAFT BENSON,
Secretary of Agriculture, Department of Agriculture,
Washington, D.C.

MY DEAR MR. SECRETARY: Reference is made to my letter of June 15, concerning the work of the Select Committee on National Water Resources. In addition to the report on use of water for agricultural crop production requested in my letter of July 1, the committee will need information and the Department's recommendations with respect to its program activities such as the small watershed program, the water facilities program, the agricultural conservation program, the rural electrification program, and others which may have a bearing on future water use in the United States. Accordingly, it is requested that a report covering the water requirements of these programs be prepared for the committee.

Principal objective of the report covering these subjects should be to inform the committee as to how the Nation's needs for these services and activities can best be met and estimated water requirements resulting from such programs between now and 1980 and looking ahead to 2000 or 2010.

The report on the watershed protection water facilities and agricultural conservation programs should contain the Department's best estimates as to the present effects of these programs on the Nation's water supplies with estimates of future effects on the basis of the Department's estimates of the Nation's future needs in these fields. We would like to have information on the number and approximate average surface area and capacity of reservoirs, stock ponds, and other facilities for the storage of water constructed under the several programs of the Department, as well as any information available on similar facilities which may be constructed without Federal assistance. Estimates of evaporation from present and potential future facilities of this nature and estimates of other gains and losses in water supplies, both onsite and downstream, as a result of these programs should be included, broken down as practicable between the land-treatment and the structural measures. We are interested both in withdrawals and net depletions. All of this information should be broken down by river basin or region with estimates of probable costs and benefits of future programs, effects on quality and quantity of water and acreages and types of land treated. In addition, we would like to have the Department's comments on the relationship of this program to other water conservation and development programs.

With respect to the rural electrification program, we would like to have the Department's estimates of what will be needed in the way of power generation facilities for this program and the Department's estimate of how these needs will be met between now and 1980. Complete information on estimated future power requirements, including rural, has been requested of the Federal Power Commission and public and private power groups, but it is believed that the Department's views on this subject will be a helpful supplement.

We would like the departmental water programs to be covered in a summary report of not more than 10,000 words with whatever tables, charts, appendixes, and graphic illustrations as may be considered necessary. The report on the rural electrification program should be a separate report. It would be most helpful if these reports could be furnished the committee by October 1, 1959.

The committee staff will be glad to discuss any problems that may arise in the preparation of these reports with the representatives of your Department.

Sincerely yours,

ROB'T S. KERR, *Chairman.*

U.S. DEPARTMENT OF AGRICULTURE,
Washington, D.C., December 24, 1959.

Hon. ROBERT S. KERR,
Chairman, Select Committee on National Water Resources,
U.S. Senate.

DEAR SENATOR KERR: We are pleased to comply with your letter of July 6, 1959, in which you requested information concerning program activities of the Department of Agriculture having a bearing on water use in the United States. The attached report covers all aspects of your letter except those concerning the rural electrification program. A report on that subject is being transmitted separately.

The estimates of present and future effects of agricultural programs on water supplies are based upon projected demands for food, fiber, and timber to supply an expanding population. Further, they consider technological advances which are expected to result from research and experience in the use of land, water, and other segments of agricultural and forest production.

We have followed, insofar as possible, the guides set forth in your letter. It must be recognized, however, that this report is based on readily available information, since the time element precluded an exhaustive analysis. In fact, adequate research data are not available to provide technically accurate answers to all of the questions. In view of this, it has been necessary to make numerous assumptions and judgment estimates which could significantly influence the results. Necessary explanations are contained throughout the report to indicate methods used, limitations, and other important considerations in the use of these data.

We shall be glad to furnish any further data which your committee may require.

Sincerely yours,

E. L. PETERSON, *Assistant Secretary.*

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ESTIMATED WATER REQUIREMENTS FOR AGRICULTURAL PURPOSES AND THEIR EFFECTS ON WATER SUPPLIES

Summary

This report presents estimates of water requirements for future agricultural developments and their effect on onsite and downstream water yield. Agricultural developments are defined as land-use changes and treatment; the installation of structural measures which include the storage of water, such as farm ponds, small storage reservoirs for irrigation, rural domestic use, national forest resource use and protection, and floodwater-retarding structures which incorporate some storage; and increases in the acreage irrigated. All estimates are based on medium population levels of 244 million in 1980, 329 million in 2000, and the assumptions and land-use estimates presented for these population levels in the Department's report to the Senate Select Committee on National Water Resources, entitled "Land and Water Potentials and Future Requirements."

More specifically, estimates are presented on the acreage of projected land-use changes, the percentage of land treatment, the number of structures, surface area of water stored, conservation and sediment pool capacities of structures, and the increase in acres irrigated. These estimates are presented for 22 water resource regions in the United States, except Alaska and Hawaii, along with estimates of their effect on water yield onsite and downstream. Onsite yield is defined as the water yield from drainage areas of 0.1 square mile (64 acres) in size. Downstream yield is defined as the water yield from drainage areas of 1,000 square miles.

The results of this study indicate that for the Nation as a whole, the projected changes in land use and treatment and the installation of structural measures will have an insignificant effect on total water yields, both onsite and downstream. This conclusion was reached by allocating present regional onsite water yield to areas of existing land use and treatment, and estimating the present onsite water yield per unit of area for each land use and treatment. The present onsite water yields per unit of area applied to projected land use provided an estimate of future onsite yields. Estimates of the effect of structural measures were based on the net decrease in downstream water yield resulting from increased water use, evaporation, and seepage. Total evaporation and seepage were estimated by applying annual values to the average surface area of water behind structures. Adjustments between onsite and downstream yield were made on the basis of existing contributions to streamflow from subsurface flow and on the basis of existing channel losses.

The effect of future irrigation requirements will depend largely on the degree of efficiency achieved in the transmission and use of irrigation water within the next 20 and 40 years.

Although this report has been prepared on the basis of improved irrigation efficiency, a summary of the estimated effects of agricultural development on downstream water yields with and without changes in irrigation efficiency is shown below.

Percent reduction in downstream water yield assuming current irrigation efficiency

Item	1980	2000
Land use and treatment	0.09	0.23
Structures	.23	.34
Irrigation	0.60	3.30
Total	.92	3.87

Percent reduction in downstream water yield assuming increased irrigation efficiency

Item	1980	2000
Land use and treatment	0.09	0.23
Structures	.23	.34
Irrigation	[1]−.68	.65
Total	[1]−.36	1.22

[1] Negative value indicates an increase in water yield.

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Although the difference between 3.87 and 1.22 percent in the year 2000 does not appear to be a major change in the water requirement, it does represent an amount of water about 1.5 times the capacity of the Lake Mead Reservoir above Hoover Dam, or approximately 50 million acre-feet. This amount could be saved annually if the assumed irrigation efficiency can be achieved by the year 2000. It is believed that the estimates of obtainable increases in efficiency are conservative, and from the physical standpoint alone, even greater efficiency could be achieved.

However, even this projected efficiency will require a high degree of cooperation of Federal and State Governments, local agencies, and water users. The Department of Agriculture, through its programs of research, education, technical assistance, cost sharing, and credit, is doing much now to achieve higher efficiency, but programs must be accelerated to reach the level of efficiency in the application of irrigation water on which this report is predicated.

The assumed level of efficiency also depends on the reduction of losses in the transmission of irrigation water and the redistribution of water saved. This will be considerably more difficult because it will depend largely on the cooperation of water users and the States in both amendment and administration of their water laws.

Scope

This report deals with the projected water requirements of land and water resource developments expected to be accomplished with assistance of the U.S. Department of Agriculture, and of similar facilities constructed without Federal assistance. Water requirements of these developments are projected for the years 1980 and 2000 by major river basins delineated in figure 1.[1]

Departmental and similar programs evaluated in this report are geared to meet the needs of a population of 244 million in 1980 and 329 million in 2000. Specific attention is given to appraising the water requirements of the resource developments most likely to be undertaken in meeting future agricultural needs.

Estimates of effects on surface water supplies of river basins were based upon the limited available data on the water requirements of major types of agricultural use and treatment, and their effect on runoff and streamflow. The factors considered in this appraisal include land use and treatments, water-impounding structures, and irrigation. Estimates of the quantities of resource improvements to be installed by the years 1980 and 2000 are based on present accomplishments of departmental programs, research, and value judgments of such factors as future need for agricultural and related products, changing technology, and alternative means of production.

The physical and economic evaluations set forth in this report should be regarded as directional rather than absolute. The many factors involved are not evaluated separately. Taken as a group, it is expected that opposing effects of individual factors will compensate in the evaluation. Long-term projections involve the measurement of many factors concerning need, production methods, and output.

The report emphasizes the need for continuing research dealing with the physical and economic aspects of agricultural water use, watershed management, and ground water. It also stresses the relation of programs of the U.S. Department of Agriculture to other water conservation developments.

Anticipated Accomplishments Which May Affect Water Supply

There are three segments of activities in agriculture and forestry which will affect water yield to some extent. They are: land use and treatment, structures, and irrigation. In this report each of these segments has been considered separately, and projected changes by the years 1980 and 2000 are listed for each of the 22 water resource regions.

Land use and treatment

The 1954 census provided the basis for present land-use estimates shown in table 1. Some modifications were made in the 1954 figures where more recent estimates were available. Tables 2 and 3 present projections of major uses of land in the years 1980 and 2000. These projections were taken from the Department's report[2] in reply to the July 1, 1959, letter from the U.S. Senate Select Committee on National Water Resources, and are based on projected agricultural requirements for a total population of 244 million in 1980 and 329 million in 2000.

[1] Appears with fig. 3-13, following p. 23.

[2] Committee Print No. 12.

"Cropland" in these tables includes cropland harvested, crop failures, cultivated summer fallow, soil-improvement crops, newly planted crops, idle cropland, and cropland used only for pasture.

"Open pasture and grazing lands" includes open permanent pasture in farms, open grazing land not in farms, other grassland, and nonforest grazing land.

"Woodland and forest" includes woodland pasture in farms, woodland and forest land not in farms, and forest land in special-use areas, such as parks.

"Other land" comprises special-use areas such as urban and transportation areas, parks, national defense sites, and all other land unaccounted for in the other three major uses.

Present and projected major uses of land do not reflect the application of land treatment to lands in each use. "Land treatment" as used in this report refers to the use of land within its capabilities and the application of soil and water conservation measures and practices, singly or in combination. These measures and practices, such as contour cultivation, terracing, and reforestation, are the ones found from research and experience to be most effective and practicable in the operation of farm, forest, and other lands, and include prospective advances in technology for the years 1980 and 2000. Table 4 lists the estimated percentage of land treatment in each of the water resource regions at present and in 1980 and 2000.

Estimates of land treatment are based on judgment, limited records, and the assumption that current levels of assistance will be maintained. The national inventory of soil and water conservation needs, scheduled for completion in 1970, will provide information on various land uses in each county in the United States. Therefore, estimates of present land treatment in this report must be considered tentative and subject to more accurate evaluation when the inventory data are available.

It must be recognized, however, that present land use does not reflect current national needs. The increased need for food and fiber during World War II resulted in the cropping of much land not suited for continuous cultivation. Since

TABLE 1.—*Major uses of land by water resource regions, 1959, excluding Alaska and Hawaii*

[Thousand acres]

Water resource region	Cropland	Open pasture and grazing land	Woodland and forest [1]	Other land	Total land area
Eastern:					
New England	3,069	793	29,658	3,779	37,299
Delaware and Hudson	5,033	1,304	11,422	4,649	22,408
Chesapeake Bay	9,842	3,629	23,112	4,267	40,850
Southeast	33,723	12,915	109,629	12,530	168,797
Eastern Great Lakes	7,630	2,153	9,755	10,781	30,299
Western Great Lakes	16,309	1,431	31,427	7,561	56,728
Ohio	41,173	9,143	33,258	7,479	91,053
Cumberland	3,723	676	5,853	943	11,195
Tennessee	6,910	2,241	17,067	2,705	28,923
Upper Mississippi	65,479	9,869	25,427	14,941	115,716
Lower Mississippi	13,812	3,194	10,093	1,585	28,684
Lower Missouri	17,537	6,513	6,503	3,526	34,189
Lower Arkansas, White, Red	16,437	10,770	38,339	4,979	70,528
Subtotal	240,657	64,627	354,642	84,728	744,654
Western:					
Upper Missouri	110,919	170,768	30,471	10,846	323,004
Upper Arkansas, White, Red	37,307	55,918	10,765	5,140	109,130
Western Gulf	29,652	51,300	26,487	13,762	121,161
Upper Rio Grande-Pecos	2,676	58,527	19,511	7,084	88,198
Colorado	4,954	89,243	14,247	24,780	133,224
Great Basin	3,341	63,617	24,812	20,003	111,773
Pacific Northwest	18,099	47,640	84,115	7,849	157,703
Central Pacific	11,205	9,690	37,805	8,115	66,281
South Pacific	1,779	5,825	5,867	12,784	26,255
Subtotal	219,932	546,851	283,870	109,475	1,159,171
United States	459,649	611,461	638,512	194,203	1,903,825

[1] All land classified as forest land, 1959 estimates, by U.S.D.A. Forest Service.

TABLE 2.—*Projected major uses of land at medium population levels, by water resource regions, 1980, excluding Alaska and Hawaii*

[Thousand acres]

Water resource region	Cropland	Open pasture and grazing land	Woodland and forest	Other land	Total land area
Eastern:					
New England	3,000	1,000	29,000	4,299	37,299
Delaware and Hudson	4,000	1,000	9,000	8,408	22,408
Chesapeake Bay	10,000	3,000	21,000	6,850	40,850
Southeast	40,000	9,000	90,000	29,800	168,800
Eastern Great Lakes	12,000	2,000	9,000	7,299	30,299
Western Great Lakes	16,000	4,000	29,000	8,728	56,728
Ohio	40,000	9,000	30,000	12,053	91,053
Cumberland	3,500	1,000	5,500	1,197	11,197
Tennessee	7,000	2,000	14,000	5,923	28,923
Upper Mississippi	70,000	5,000	24,000	16,716	115,716
Lower Mississippi	18,000	6,000	13,000	1,684	28,684
Lower Missouri	18,000	7,000	7,000	4,189	34,189
Lower Arkansas, White, Red	19,000	9,000	35,000	7,528	70,528
Subtotal	261,500	76,000	321,500	106,654	744,654
Western:					
Upper Missouri	130,000	103,000	30,000	14,004	323,004
Upper Arkansas, White, Red	37,000	53,000	11,000	8,130	109,130
Western Gulf	32,000	38,000	26,000	25,161	121,161
Upper Rio Grande-Pecos	3,000	59,000	19,000	7,198	88,198
Colorado	4,000	88,000	14,000	19,224	125,224
Great Basin	3,500	63,000	25,000	19,273	111,773
Pacific Northwest	18,000	48,000	83,000	8,703	157,703
Central Pacific	11,000	7,000	36,000	12,281	66,281
South Pacific	1,500	6,000	5,000	13,755	26,255
Subtotal	240,000	465,000	279,000	127,171	1,159,171
United States	501,500	541,000	600,500	233,825	1,903,825

[1] Estimates of cropland, pasture, and forest are generally made to nearest million acres. Projected shifts in land use embodied in this table apply only to physical potential. The full realization of land-use shifts, particularly to more intensive use, is not necessarily recommended or economically desirable under present conditions.

World War II, price-support programs have encouraged the continued use of such land for crops, and have acted as a deterrent to the application of effective soil and water conservation measures.

TABLE 3.—*Projected major uses of land at medium population levels, by water resource regions, 2000, excluding Alaska and Hawaii*[1]

[Thousand acres]

Water resource region	Cropland	Open pasture and grazing land	Woodland and forest	Other land	Total land area
Eastern:					
New England	3,000	1,000	27,000	6,299	37,299
Delaware and Hudson	3,000	1,000	7,000	11,408	22,408
Chesapeake Bay	12,000	2,000	18,000	8,850	40,850
Southeast	54,000	9,000	85,000	20,800	168,800
Eastern Great Lakes	12,000	1,000	7,000	10,299	30,299
Western Great Lakes	18,000	3,000	26,000	11,728	56,728
Ohio	42,000	8,000	27,000	14,033	91,033
Cumberland	4,000	1,000	5,000	1,197	11,197
Tennessee	9,000	2,000	14,000	1,923	26,923
Upper Mississippi	75,000	5,000	22,000	13,716	115,716
Lower Mississippi	18,000	6,000	12,000	2,684	38,684
Lower Missouri	18,000	5,000	6,000	5,189	34,189
Lower Arkansas, White, Red	25,000	8,000	34,000	3,528	70,528
Subtotal	291,000	52,000	290,000	111,654	744,654
Western:					
Upper Missouri	111,000	169,000	30,000	13,004	323,004
Upper Arkansas, White, Red	38,000	53,000	11,000	7,130	109,130
Western Gulf	62,000	47,000	25,000	17,101	121,101
Upper Rio Grande-Pecos	3,000	58,000	19,000	8,198	88,198
Colorado	7,000	88,000	11,000	19,724	135,724
Great Basin	4,000	65,000	25,000	17,775	111,775
Pacific Northwest	18,000	48,000	82,000	9,703	157,703
Central Pacific	11,000	6,000	34,000	15,281	66,281
South Pacific	1,000	5,000	4,000	16,255	26,255
Subtotal	252,000	529,000	274,000	124,171	1,159,171
United States	543,000	581,000	564,000	235,825	1,903,825

[1] Estimates of cropland, pasture, and forest are generally made to nearest million acres. Projected shifts in land use embodied in this table apply only to physical potential. The full realization of land-use shifts (particularly to more intensive use) is not necessarily recommended or economically desirable under present conditions.

TABLE 4.—*Estimated percent of land treatment installed, by water resource regions—Present, 1980, and 2000*[1]

Water resource region	Present	1980	2000
New England	16	31	46
Delaware and Hudson	17	34	49
Chesapeake Bay	17	37	54
Southeast	25	45	72
Eastern Great Lakes	19	38	54
Western Great Lakes	19	28	45
Ohio	18	38	56
Cumberland	22	40	58
Tennessee	22	40	59
Upper Mississippi	16	35	55
Lower Mississippi	20	36	58
Lower Missouri	23	36	50
Lower Arkansas, White, Red	19	34	56
Upper Missouri	21	34	54
Upper Arkansas, White, Red	13	24	38
Western Gulf	16	28	52
Upper Rio Grande-Pecos	6	21	35
Colorado	14	26	47
Great Basin	7	16	30
Pacific Northwest	27	40	58
Central Pacific	18	35	48
South Pacific	11	20	34

[1] Percentages refer to the total of those areas in tables 1, 2, and 3 shown as "cropland," "open pasture and grazing land," and "woodland and forest."

Structures

Estimates of the present number of farm and ranch ponds and reservoirs are based on reports of various agencies of the Department. Total needs estimates were obtained from Soil Conservation Service reports, and trend lines on the rate of construction (1954–57) indicate that the total requirements will be met before the year 2000. The estimates of surface area and storage capacity were developed for each river basin on the basis of ponds and reservoirs already built.

It is recognized that in some areas the number and location of stock ponds have not always been in the best interest of full and productive use of water. The Department is continually improving its standards in the construction and distribution of farm ponds. Where assistance is provided, every effort is being made to construct ponds in the best interest of full and productive use of water.

The number, surface area, and capacity of other watershed structures were based on data taken from plans for authorized watershed projects. Estimates for the years 1980 and 2000 are based on the assumption that Federal expenditures for watershed protection and flood prevention operations will keep abreast of the need for a gradual strengthening and an increase during the next several years in such operations. If this objective is realized, about 80 percent of the watersheds now feasible of treatment under Public Law 566 would be completed by the year 2000.

Most of the projections were made without modification of experienced trends, except where it was obvious that changes were now taking place. The estimate of conservation storage capacity to be developed in watershed structures was projected higher than past trends would indicate. This was done because of the apparent interest in developing more conservation storage. However, in estimating conservation storage capacity in Western States, it was assumed that established appropriations of water would make it difficult, if not preclude, substantial increases in conservation capacity development in watershed structures.

Table 5 lists the estimated total structural measures which will involve the permanent storage of water. The table does not include grade stabilization structures, debris basins, and

other structures which may retard flow but contain no permanent storage. Likewise, the acre-feet of storage capacity shown includes only permanent and sediment pool storage. It does not include estimates of reservoir capacity for temporary storage of floodwaters.

Irrigation

Details regarding the estimated acreage of land under irrigation by 1980 and 2000 are presented in the Department's report [3] in reply to the July 1, 1959, letter from the U.S. Senate Select Committee on National Water Resources. Table 6 presents the additional acres of land to be brought under irrigation by 1980 and 2000, based on population levels of 244 million in 1980 and 329 million in 2000.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*

SUMMARY—22 WATER RESOURCE REGIONS

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	912,750	632,312	449,980	2,126,765
1980	do	1,991,350	1,344,586	975,215	4,135,570
2000	do	2,375,050	1,594,760	1,157,430	4,893,090
1959	Other reservoirs [2]	23,462	155,698	96,886	719,680
1980	do [2]	79,700	495,600	312,050	2,256,500
2000	do [2]	95,533	588,991	371,390	2,674,570
1959	Watershed structures	1,802	53,336	37,944	283,118
1980	do	47,300	675,700	510,480	3,720,000
2000	do	35,700	1,373,300	1,040,270	7,292,000
1959	Total structural measures	938,014	841,346	584,810	3,129,563
1980	do	2,068,350	2,515,886	1,797,745	10,112,470
2000	do	2,506,283	3,557,051	2,569,090	14,859,360
	NEW ENGLAND				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	7,000	3,500	2,800	8,400
1980	do	31,900	15,950	12,760	38,280
2000	do	40,400	20,200	16,160	48,480
1959	Other reservoirs	350	1,050	700	3,500
1980	do	1,900	5,700	3,800	19,000
2000	do	2,450	7,350	4,900	24,500
1959	Watershed structures	13	100	90	200
1980	do	200	9,400	8,270	53,000
2000	do	420	19,500	17,200	160,000
1959	Total structural measures	7,363	4,650	3,590	12,100
1980	do	34,000	31,050	24,830	110,280
2000	do	43,270	47,050	38,260	232,980
	DELAWARE AND HUDSON				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	4,850	2,425	1,940	5,820
1980	do	20,250	10,125	8,100	24,300
2000	do	25,600	12,800	10,240	30,720
1959	Other reservoirs	900	3,600	2,700	13,500
1980	do	3,300	13,200	9,900	49,500
2000	do	4,300	17,200	12,900	64,500

[3] Committee Print No. 12.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*—Continued

DELAWARE AND HUDSON—Continued

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Watershed structures	16	300	260	1,100
1980	do	120	11,300	9,940	78,000
2000	do	230	23,700	20,800	154,000
1959	Total structural measures	5,766	6,325	4,900	20,420
1980	do	23,670	34,625	27,940	151,800
2000	do	30,130	53,700	43,940	249,220
	CHESAPEAKE BAY				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	16,000	8,000	6,400	19,200
1980	do	49,750	24,875	19,900	59,700
2000	do	62,900	31,450	25,160	75,480
1959	Other reservoirs	900	3,600	2,700	13,500
1980	do	5,550	22,200	16,650	83,250
2000	do	7,200	28,800	21,600	108,000
1959	Watershed structures	160	2,800	2,300	14,500
1980	do	620	33,900	27,800	200,000
2000	do	1,160	63,000	51,700	367,000
1959	Total structural measures	17,060	14,400	11,400	47,200
1980	do	55,920	80,975	64,350	342,950
2000	do	71,260	123,250	98,460	550,480
	SOUTHEAST				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	126,800	95,100	76,080	228,240
1980	do	294,350	220,762	176,610	529,830
2000	do	346,300	259,725	207,780	623,340
1959	Other reservoirs	8,200	41,000	24,600	164,000
1980	do	23,150	115,750	69,450	463,000
2000	do	27,250	136,250	81,750	545,000
1959	Watershed structures	220	4,600	3,800	22,000
1980	do	1,730	105,000	86,000	630,000
2000	do	3,470	213,000	175,000	1,225,000
1959	Total structural measures	135,220	140,700	104,480	414,240
1980	do	319,230	441,512	332,060	1,622,830
2000	do	377,020	608,975	464,530	2,393,340
	EASTERN GREAT LAKES				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	12,150	6,075	4,860	14,580
1980	do	42,750	21,375	17,900	51,300
2000	do	54,100	27,050	21,640	64,920
1959	Other reservoirs	750	4,500	3,000	22,500
1980	do	1,000	6,000	4,000	30,000
2000	do	7	100	90	100
1959	Watershed structures	120	4,000	3,520	22,000
1980	do	270	8,600	7,570	47,000
2000	do	12,157	6,175	4,950	14,680
1959	Total structural measures	43,620	29,875	23,620	95,800
1980	do	55,370	41,650	33,210	141,920
2000	do				
	WESTERN GREAT LAKES				
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	2,850	2,138	1,995	5,130
1980	do	9,700	7,275	6,790	17,460
2000	do	11,950	8,962	8,365	21,510
1959	Other reservoirs	1,500	9,000	6,000	45,000
1980	do	2,000	12,000	8,000	60,000
2000	do	50	6,200	5,100	35,000
1959	Watershed structures	110	13,300	10,900	75,000
1980	do	2,850	2,138	1,995	5,130
2000	do	11,250	22,475	17,890	97,460
1980	Total structural measures	14,060	34,262	27,265	156,510
2000	do				

Footnotes at end of table.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*—Continued

OHIO

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	85,150	42,575	34,060	102,180
1980	do	222,450	111,225	88,980	266,940
2000	do	274,650	137,325	109,860	329,580
1959	Other reservoirs	150	750	450	3,000
1980	do	3,900	19,500	11,700	78,000
2000	do	5,200	26,000	15,600	104,000
1959	Watershed structures	60	3,200	2,620	27,500
1980	do	1,450	54,600	42,300	337,000
2000	do	3,090	110,000	90,000	680,000
1959	Total structural measures	85,360	46,525	37,130	132,680
1980	do	227,800	182,325	142,980	681,940
2000	do	282,940	273,325	215,460	1,113,580

CUMBERLAND

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	23,200	11,600	9,280	27,840
1980	do	54,850	27,425	21,940	65,820
2000	do	66,100	33,050	26,440	79,320
1959	Other reservoirs				
1980	do				
2000	do				
1959	Watershed structures	23	200	160	1,700
1980	do	350	5,690	4,300	31,000
2000	do	740	11,900	9,800	61,000
1959	Total structural measures	23,223	11,800	9,440	29,540
1980	do	55,200	33,025	26,540	96,820
2000	do	66,840	44,950	36,240	140,320

TENNESSEE

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	33,250	24,938	23,275	59,850
1980	do	80,950	60,712	56,665	145,710
2000	do	95,200	71,400	66,640	171,360
1959	Other reservoirs	150	450	300	1,500
1980	do	1,100	3,300	2,200	11,000
2000	do	1,277	3,831	2,554	12,770
1959	Watershed structures	50	1,000	820	5,400
1980	do	680	17,000	14,700	88,000
2000	do	1,430	37,400	30,700	165,000
1959	Total structural measures	33,450	26,388	24,395	66,750
1980	do	82,730	81,912	73,565	244,710
2000	do	97,907	112,631	99,894	349,130

UPPER MISSISSIPPI

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	31,100	15,550	12,440	43,540
1980	do	109,550	54,775	43,820	153,370
2000	do	135,250	67,625	54,100	189,350
1959	Other reservoirs				
1980	do	1,900	15,200	9,500	76,000
2000	do	2,500	20,000	12,500	100,000
1959	Watershed structures	30	100	80	400
1980	do	620	22,800	18,700	172,000
2000	do	1,320	54,000	44,300	363,000
1959	Total structural measures	31,130	15,650	12,520	43,940
1980	do	112,070	92,775	72,020	401,370
2000	do	139,070	141,625	110,900	652,350

LOWER MISSISSIPPI

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	49,900	24,950	19,960	59,880
1980	do	97,700	48,850	39,080	117,240
2000	do	114,900	57,450	45,960	137,880
1959	Other reservoirs	312	1,248	936	4,680
1980	do	900	3,600	2,700	13,500
2000	do	1,050	4,200	3,150	15,750
1959	Watershed structures	30	1,400	1,150	2,500
1980	do	620	47,000	38,500	93,000
2000	do	1,360	100,000	82,000	186,000
1959	Total structural measures	50,242	27,598	22,046	67,060
1980	do	99,220	99,450	80,280	223,740
2000	do	117,310	161,650	131,110	339,630

Footnotes at end of table.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*—Continued

LOWER MISSOURI

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	16,100	12,075	9,660	38,640
1980	do	47,750	35,812	28,650	114,600
2000	do	58,950	44,212	35,370	141,480
1959	Other reservoirs				
1980	do	850	4,250	2,550	17,000
2000	do	1,100	5,500	3,300	22,000
1959	Watershed structures	30	2,700	2,200	11,400
1980	do	210	28,800	23,600	129,000
2000	do	430	55,900	45,800	241,000
1959	Total structural measures	16,130	14,775	11,860	50,040
1980	do	48,810	68,862	54,800	260,600
2000	do	60,480	105,612	84,470	404,480

LOWER ARKANSAS, WHITE, RED

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	81,150	60,862	40,575	170,415
1980	do	151,400	113,550	75,700	317,940
2000	do	178,150	133,612	89,075	374,115
1959	Other reservoirs	1,550	15,500	9,300	77,500
1980	do	4,700	47,000	28,200	235,000
2000	do	5,506	55,060	33,036	275,300
1959	Watershed structures	30	800	580	3,400
1980	do	2,700	97,300	70,000	418,000
2000	do	5,900	210,000	151,000	821,000
1959	Total structural measures	82,730	77,162	50,455	251,315
1980	do	158,800	257,850	173,900	970,940
2000	do	189,556	398,672	273,111	1,479,415

UPPER MISSOURI

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	126,750	95,062	63,375	380,250
1980	do	236,650	177,488	118,325	709,950
2000	do	269,700	202,275	134,850	809,100
1959	Other reservoirs	2,450	24,500	14,700	122,500
1980	do	5,750	57,500	34,500	287,500
2000	do	6,650	66,500	39,900	332,500
1959	Watershed structures	100	1,400	1,000	10,500
1980	do	1,340	33,700	24,300	334,000
2000	do	2,820	70,000	50,400	680,000
1959	Total structural measures	128,300	120,962	79,075	513,250
1980	do	243,740	268,688	177,125	1,331,450
2000	do	279,170	338,775	225,150	1,821,600

UPPER ARKANSAS, WHITE, RED

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	125,900	94,425	62,950	339,930
1980	do	205,000	153,750	102,500	553,500
2000	do	232,950	174,712	116,475	628,965
1959	Other reservoirs	500	3,000	2,000	15,000
1980	do	2,150	12,900	8,600	64,500
2000	do	2,500	15,000	10,000	75,000
1959	Watershed structures	540	10,700	7,100	58,000
1980	do	3,580	72,000	47,500	363,000
2000	do	7,200	144,000	95,000	730,000
1959	Total structural measures	126,940	180,125	72,050	412,930
1980	do	210,730	238,650	158,600	981,000
2000	do	242,650	333,712	221,475	1,433,965

WESTERN GULF

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	99,900	74,925	49,950	239,760
1980	do	199,400	149,550	99,700	478,560
2000	do	226,600	169,950	113,300	543,840
1959	Other reservoirs	800	3,200	2,400	12,000
1980	do	3,650	14,600	10,950	54,750
2000	do	4,250	17,000	12,750	63,750
1959	Watershed structures	460	23,400	15,400	120,000
1980	do	1,380	101,300	67,000	455,000
2000	do	2,460	179,000	118,000	737,000
1959	Total structural measures	101,160	101,525	67,750	371,760
1980	do	204,430	265,450	177,650	988,310
2000	do	233,310	365,950	244,050	1,344,590

Footnotes at end of table.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*—Continued

UPPER RIO GRANDE-PECOS

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	33,600	33,600	16,800	288,960
1980	do	62,600	62,600	31,300	300,480
2000	do	71,150	71,150	35,575	341,520
1959	Other reservoirs	1,700	13,600	8,500	68,000
1980	do	4,250	34,000	21,250	170,000
2000	do	4,950	39,600	24,750	198,000
1959	Watershed structures	14	249	126	1,750
1980	do	320	5,700	2,900	40,000
2000	do	680	12,000	6,000	86,000
1959	Total structural measures	35,314	47,449	25,426	358,710
1980	do	67,170	102,300	55,450	510,480
2000	do	76,780	122,750	66,325	625,520

COLORADO

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	17,100	12,825	6,840	51,300
1980	do	34,550	25,912	13,820	103,650
2000	do	51,100	38,325	20,440	153,300
1959	Other reservoirs	1,250	12,500	7,500	62,500
1980	do	2,050	20,500	12,300	102,500
2000	do	2,350	23,500	14,100	117,500
1959	Watershed structures	4	27	13	508
1980	do	300	2,000	1,000	38,000
2000	do	640	5,000	2,500	82,000
1959	Total structural measures	18,354	25,352	14,353	114,308
1980	do	36,900	48,412	27,120	244,150
2000	do	54,090	66,825	37,040	352,800

GREAT BASIN

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	4,950	3,712	1,980	17,820
1980	do	10,700	8,025	4,280	38,520
2000	do	15,750	11,812	6,300	56,700
1959	Other reservoirs	400	2,400	1,600	12,000
1980	do	900	5,400	3,600	27,000
2000	do	1,050	6,300	4,200	31,500
1959	Watershed structures	10	100	50	500
1980	do	280	900	450	20,000
2000	do	600	2,000	1,000	42,000
1959	Total structural measures	5,360	6,212	3,630	30,320
1980	do	11,880	14,325	8,330	85,520
2000	do	17,400	20,112	11,500	130,200

PACIFIC NORTHWEST

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	9,000	4,950	2,700	16,200
1980	do	17,450	8,725	5,235	31,410
2000	do	26,000	13,000	7,800	46,800
1959	Other reservoirs	1,450	11,600	7,250	58,000
1980	do	5,050	40,400	25,250	202,000
2000	do	5,700	45,600	28,500	228,000
1959	Watershed structures				
1980	do	300	9,200	8,100	91,000
2000	do	670	20,000	17,600	191,000
1959	Total structural measures	10,450	16,550	9,950	74,200
1980	do	22,800	58,325	38,585	324,410
2000	do	32,370	78,600	53,900	468,800

CENTRAL PACIFIC

			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	4,250	2,125	1,700	5,950
1980	do	8,150	4,075	3,260	11,410
2000	do	12,150	6,075	4,860	17,010
1959	Other reservoirs	1,650	13,200	8,250	66,000
1980	do	4,350	34,800	21,750	174,000
2000	do	4,900	39,200	24,500	196,000
1959	Watershed structures	5	35	105	1,060
1980	do	220	7,100	4,700	73,000
2000	do	480	15,400	10,200	157,000
1959	Total structural measures	5,905	15,485	10,055	73,010
1980	do	12,720	45,975	29,710	258,410
2000	do	17,530	60,675	39,560	370,010

Footnotes at end of table.

TABLE 5.—*Estimated structural measures—1959, 1980, 2000*—Continued

SOUTH PACIFIC

Year	Item	Number	Summation		
			Maximum surface	Average surface	Storage capacities [1]
			Acres	*Acres*	*Acre-feet*
1959	Stock ponds	1,800	900	360	2,880
1980	do	3,500	1,750	700	5,600
2000	do	5,200	2,600	1,040	8,320
1959	Other reservoirs	750	4,500	3,000	22,500
1980	do	2,050	12,300	8,200	61,500
2000	do	2,350	14,100	9,400	70,500
1959	Watershed structures				
1980	do	110	3,000	1,500	20,000
2000	do	220	5,600	2,800	39,000
1959	Total structural measures	2,550	5,400	3,360	25,380
1980	do	5,660	17,050	10,400	87,100
2000	do	7,770	22,300	13,240	117,820

[1] Conservation and sediment pool capacities only.
[2] Small reservoirs for special purposes such as irrigation, fire control, recreation in national forests, etc.

TABLE 6.—*Increase in acres irrigated by 1980 and 2000* [1]

Water resource region	Estimated irrigated acres—1957	Increases by 1980	Increases by 2000
Eastern:			
New England	44,984	35,038	202,518
Delaware and Hudson	137,384	57,337	227,002
Chesapeake Bay	41,831	36,050	795,478
Southeast	622,540	456,757	3,733,195
Eastern Great Lakes	27,431	14,130	417,928
Western Great Lakes	33,601	37,280	631,276
Ohio	41,928	50,844	1,046,861
Cumberland	4,816	1,849	65,961
Tennessee	24,307	9,194	172,255
Upper Mississippi	41,499	59,635	2,492,154
Lower Mississippi	636,994	281,067	1,126,450
Lower Missouri	9,503	11,135	740,300
Lower Arkansas, White, Red	708,908	280,722	1,039,802
Subtotal	2,375,316	1,331,038	12,691,180
Western:			
Upper Missouri	5,368,901	917,928	4,340,216
Upper Arkansas, White, Red	1,637,240	44,083	600,157
Western Gulf	5,147,944	[2]—22,313	1,673,322
Upper Rio Grande-Pecos	1,315,246	100,531	295,444
Colorado	3,268,144	11,737	71,927
Great Basin	2,248,649	8,689	70,878
Pacific Northwest	5,056,955	204,624	1,522,151
Central Pacific	7,043,970	[2]—175,062	[2]—58,994
South Pacific	917,177	[2]—101,452	[2]—74,471
Subtotal	32,004,227	988,775	8,440,630
United States	34,380,043	2,319,813	21,131,810

[1] Based on estimates presented in table 11 (1957) and table 45 (1980 and 2000 medium population levels) in the Department's report in reply to the July 1, 1959, letter from the U.S. Senate Select Committee on National Water Resources.
[2] Anticipated decrease in acres irrigated resulting from urbanization.

ESTIMATED WATER REQUIREMENTS

Land use and treatment

Projected changes in land use and treatment to meet the needs for food and fiber at the medium population levels in 1980 and 2000, and at the same time conserve our soil resource, will result in some increase in total water requirements. Existing data on the runoff from various land uses and treatments have been applied to the projected future conditions. (See tables 2, 3, and 4.) The

estimated total water requirements for this change in land use and treatment are presented in table 7. The requirement is shown both onsite (0.1 square-mile drainage area) and downstream (1,000 square-mile drainage area) so that its effect on streamflow may be similarly shown.

Structures

The estimated additional water requirements resulting from the installation of the structural measures (see table 5) are based on the net evaporation and seepage resulting from the storage of water, plus anticipated onfarm water use (exclusive of irrigation). Table 8 lists this requirement in acre-feet at the structure site and downstream.

Irrigation

The expected increase in irrigated land by 1980 and 2000 is shown in table 6. The total irrigation requirement in terms of acre-feet per acre irrigated was developed for each of the water resource regions. (See table 40 of the Department's report, "Land and Water Potentials and Future Requirements," for the U.S. Senate Select Committee on National Water Resources.)[4] Table 9 lists the changes in water requirement for irrigation. Negative values indicate net gains in water supply resulting primarily from increased efficiency in use and transmission of irrigation water. No onsite requirement is shown, since the demand for irrigation water will in all cases be a downstream demand (from drainage areas greater than 0.1 square mile).

It should be noted that if no increase is made in the efficiency of application and transmission of irrigation water, an additional 56 million acre-feet will be required in 2000 to meet crop and pasture production requirements. With reasonable efficiency in the transmission and use of irrigation water, the same production levels could be reached with only 4 million additional acre-feet. In other words, approximately 50 million acre-feet of water, or the equivalent of 1.5 times the storage capacity of the Lake Mead Reservoir above Hoover Dam, could be saved annually.

[4] Committee Print No. 12.

TABLE 7.—*Estimated additional water requirement for projected land use and treatment, 1980 and 2000*

[Thousand acre-feet]

Water resource regions	1980		2000	
	Onsite [1]	Downstream [2]	Onsite [1]	Downstream [2]
Eastern:				
New England	583	432	629	466
Delaware and Hudson	[3] −287	−154	−553	−297
Chesapeake Bay	58	42	−108	−80
Southeast	−26	−18	264	187
Eastern Great Lakes	132	83	−119	−74
Western Great Lakes	53	31	133	79
Ohio	100	75	185	139
Cumberland	56	33	95	56
Tennessee	63	31	320	158
Upper Mississippi	108	92	379	322
Lower Mississippi	67	50	194	144
Lower Missouri	64	56	96	83
Lower Arkansas, White, Red	11	7	408	266
Subtotal	982	760	1,923	1,449
Western:				
Upper Missouri	656	414	1,968	1,242
Upper Arkansas, White, Red	34	12	102	36
Western Gulf	−152	−68	397	178
Upper Rio Grande-Pecos	55	17	97	28
Colorado	195	27	365	51
Great Basin	35	3	88	7
Pacific Northwest	197	52	443	116
Central Pacific	62	23	52	19
South Pacific	−29	−2	−70	−4
Subtotal	1,053	478	3,442	1,673
United States	2,035	1,238	5,365	3,122

[1] Onsite—at drainage area of 0.1 square mile.
[2] Downstream—at drainage area of 1,000 square miles.
[3] Negative values indicate a decrease in the annual water requirement.

TABLE 8.—*Estimated additional annual water requirement for structural measures, 1980 and 2000*

[Thousand acre-feet]

Water resource regions	Total requirement at structure site		Total downstream [1] requirement	
	1980	2000	1980	2000
Eastern:				
New England	63	88	62	86
Delaware and Hudson	58	86	58	86
Chesapeake Bay	123	179	123	179
Southeast	561	766	562	765
Eastern Great Lakes	69	96	67	94
Western Great Lakes	39	55	35	49
Ohio	317	453	317	452
Cumberland	60	84	60	83
Tennessee	114	152	106	141
Upper Mississippi	217	305	217	304
Lower Mississippi	135	208	135	208
Lower Missouri	128	190	124	183
Lower Arkansas, White, Red	340	537	301	474
Subtotal	2,224	3,199	2,167	3,104
Western:				
Upper Missouri	484	666	323	444
Upper Arkansas, White, Red	452	719	213	331
Western Gulf	519	761	299	437
Upper Rio Grande-Pecos	203	271	95	125
Colorado	77	139	32	56
Great Basin	25	43	3	7
Pacific Northwest	73	110	52	76
Central Pacific	74	110	59	88
South Pacific	44	62	5	7
Subtotal	1,951	2,881	1,081	1,571
United States	4,175	6,080	3,248	4,675

[1] Downstream—at drainage area of 1,000 square miles.

TABLE 9.—*Estimated annual water requirements for irrigation, 1957, 1980, and 2000*

[Thousand acre-feet]

Water resource region	Total ground-water and surface-water requirements					Surface-water requirement at estimated future efficiency			Additional surface-water requirement at estimated future efficiency	
	At current efficiency [1]			At estimated future efficiency						
	1957 [2]	1980	2000	1980	2000	1957	1980	2000	1980	2000
Eastern:										
New England	54	96	297	80	247	49	73	225	24	176
Delaware-Hudson	220	312	583	292	437	110	146	219	36	109
Chesapeake Bay	84	156	1,675	132	1,256	77	121	1,156	44	1,079
Southeast	1,743	3,022	12,196	2,374	8,711	906	1,234	4,530	328	3,624
Eastern Great Lakes	44	66	713	54	546	32	39	399	7	367
Western Great Lakes	67	142	1,330	120	997	58	103	857	45	799
Ohio	84	186	2,178	158	1,633	59	111	1,143	52	1,084
Cumberland	8	11	113	9	85	7	8	78	1	71
Tennessee	44	60	354	57	275	40	52	253	12	213
Upper Mississippi	100	243	6,081	212	4,561	56	119	2,554	63	2,498
Lower Mississippi	1,502	2,295	4,409	2,020	3,351	605	768	1,273	163	668
Lower Missouri	21	45	1,650	39	1,350	18	34	1,161	16	1,143
Lower Arkansas, White, Red	1,500	2,177	3,847	1,880	3,148	437	526	881	89	444
Subtotal	5,621	8,811	35,426	7,427	26,597	2,454	3,334	14,729	880	12,275
Western:										
Upper Missouri	17,717	20,747	32,040	16,346	22,331	15,237	14,058	19,205	[3] −1,179	3,968
Upper Arkansas, White, Red	4,748	4,876	6,488	4,035	4,922	3,329	1,130	1,378	−199	49
Western Gulf	11,840	11,789	15,689	9,226	10,914	5,328	4,613	6,003	−715	675
Upper Rio Grande-Pecos	6,576	7,079	8,653	5,522	5,315	2,959	2,761	2,923	−198	[3] −36
Colorado	20,262	20,335	20,708	16,071	14,606	14,386	12,214	11,904	−2,172	−2,482
Great Basin	9,444	9,481	9,742	7,449	6,727	8,216	6,481	5,852	−1,735	−2,364
Pacific Northwest	16,182	16,837	21,053	13,680	15,132	14,887	12,586	13,921	−2,301	−966
Central Pacific	35,924	35,031	35,623	30,223	27,241	17,962	16,623	16,345	−1,339	−1,617
South Pacific	5,044	4,486	4,635	3,671	3,371	2,522	2,019	2,023	−503	−499
Subtotal	127,737	130,661	154,031	106,223	110,649	82,826	72,485	79,554	[3] −10,341	[3] −3,272
United States	133,358	139,472	189,457	113,650	137,246	85,280	75,819	94,283	[3] −9,461	9,003

[1] Assuming no increase in efficiency of application and transmission of irrigation water.
[2] Based on adequate irrigation of all land under irrigation.
[3] Negative values indicate a net decrease in water requirements resulting from estimated increased efficiency in use and transmission of irrigation water.

ESTIMATED EFFECTS OF AGRICULTURAL PROGRAMS ON WATER SUPPLY

Onsite water supply

The only effect of agricultural programs on onsite water yield is that caused by changes in land use and treatment, since the effects of structural measures and irrigation are assumed to take place below the point considered as onsite runoff (0.1 square mile). Therefore, table 10 reflects the anticipated effect of projected land-use changes and the estimated rate of application of land treatment measures on onsite water yield in the years 1980 and 2000.

Downstream water supply

The effect of agricultural programs on downstream water yield in the years 1980 and 2000 is shown in table 11. It includes the effect of projected land use and treatment, structures, and irrigation requirements. A graphical representation of this effect is shown in figure 2. Details on the assumptions made and the method of computing these estimates are presented in the last section of this report.

TABLE 10.—*Estimated effect of agricultural programs on annual onsite water supply, 1980 and 2000* [1]

[Thousand acre-feet]

Water resource region	Onsite supply			Change in onsite supply [2]	
	Present	1980	2000	1980	2000
Eastern:					
New England	58,279	57,696	57,650	−583	−629
Delaware and Hudson	20,307	20,594	20,860	287	553
Chesapeake Bay	22,340	22,282	22,448	−58	108
Southeast	44,838	44,864	44,574	26	−264
Eastern Great Lakes	19,410	19,278	19,529	−132	119
Western Great Lakes	23,046	22,993	22,913	−53	−133
Ohio	71,120	71,020	70,935	−100	−185
Cumberland	8,048	7,992	7,953	−56	−95
Tennessee	17,248	17,185	16,928	−63	−320
Upper Mississippi	36,161	36,053	35,782	−108	−379
Lower Mississippi	24,178	24,111	23,984	−67	−194
Lower Missouri	13,355	13,291	13,259	−64	−96
Lower Arkansas, White, Red	35,264	35,253	34,856	−11	−408
Subtotal	393,594	392,612	391,671	−982	−1,923
Western:					
Upper Missouri	60,563	59,907	58,595	−656	−1,968
Upper Arkansas, White, Red	6,309	6,275	6,207	−34	−102
Western Gulf	39,736	39,888	39,339	152	−397
Upper Rio Grande-Pecos	2,205	2,150	2,108	−55	−97
Colorado	6,813	6,618	6,448	−195	−365
Great Basin	2,096	2,061	2,008	−35	−88
Pacific Northwest	13,306	13,109	12,863	−197	−443
Central Pacific	11,392	11,330	11,340	−62	−52
South Pacific	1,559	1,588	1,629	29	70
Subtotal	143,979	142,926	140,537	−1,053	−3,442
United States	537,573	535,538	532,208	−2,035	−5,365

[1] Onsite at drainage area 0.1 square mile.
[2] Negative values indicate decrease in onsite water supply.

TABLE 11.—*Estimated effect of agricultural programs on annual downstream water supply, 1980 and 2000* [1]

[Thousand acre-feet]

Water resource region	Downstream supply			Change in downstream supply [2]	
	Present	1980	2000	1980	2000
Eastern:					
New England	72,849	72,331	72,121	−518	−728
Delaware and Hudson	48,317	48,377	48,419	60	102
Chesapeake Bay	53,616	53,407	52,438	−209	−1,178
Southeast	247,925	247,053	243,349	−872	−4,576
Eastern Great Lakes	42,608	42,451	42,221	−157	−387
Western Great Lakes	53,183	53,072	52,256	−111	−927
Ohio	130,860	130,416	129,185	−444	−1,675
Cumberland	22,744	22,650	22,534	−94	−210
Tennessee	58,054	57,905	57,542	−149	−512
Upper Mississippi	75,939	75,567	72,815	−372	−3,124
Lower Mississippi	61,653	61,305	60,633	−348	−1,020
Lower Missouri	21,368	21,172	19,959	−196	−1,409
Lower Arkansas, White, Red	83,752	83,355	82,568	−397	−1,184
Subtotal	972,868	969,061	956,040	−3,807	−16,828
Western:					
Upper Missouri	54,507	54,949	48,853	442	−5,654
Upper Arkansas, White, Red	27,282	27,256	26,866	−26	−416
Western Gulf	57,712	58,196	56,422	484	−1,290
Upper Rio Grande-Pecos	18,604	18,650	18,487	86	−117
Colorado	38,931	41,044	41,306	2,113	2,375
Great Basin	8,732	10,461	11,082	1,729	2,350
Pacific Northwest	135,526	137,723	136,300	2,197	774
Central Pacific	66,281	67,538	67,791	1,257	1,510
South Pacific	1,436	1,936	1,932	500	496
Subtotal	409,011	417,793	409,039	8,782	28
United States	1,381,879	1,386,854	1,365,079	4,975	−16,800

[1] Downstream at drainage area 1,000 square miles.
[2] Negative values indicate a decrease in downstream water supply.

ESTIMATE OF THE EFFECT OF AGRICULTURAL PROGRAMS
on
DOWNSTREAM WATER YIELDS

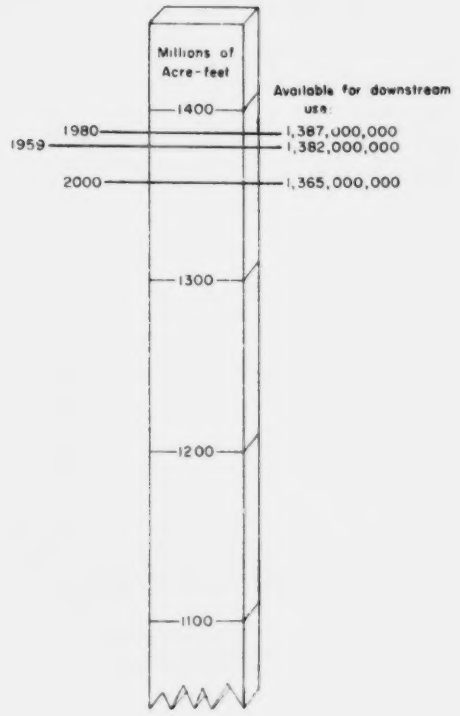


FIGURE 2

BENEFITS AND COSTS OF USDA PROGRAMS

The Congress has recognized, in prior national legislation providing for Federal assistance in soil and water conservation and forest protection and management, that such assistance is in the public interest. The Department has found through experience that land-treatment measures installed with such assistance produce combined public and private benefits in excess of their costs. Therefore, for purposes of this report, the discussion of benefits and costs is confined to the structural measures included in the watershed protection and flood prevention programs participated in by the Department.

Agriculture's land and water development programs include a number of purposes, with several kinds of benefits stemming from them. A summary of the various types of benefits from 160 Public Law 566 watershed projects in all parts of the United States reveals that 75 percent of all benefits are agricultural. The most important agricultural benefit is reduction in floodwater damages, constituting 40 percent of the total benefits. Substantial nonagricultural benefits also accrue, such as the reduction in flood damages to highways, railroads, and urban areas. Next in importance are benefits from restoration of damaged flood-plain lands to their former productivity. Significant benefits also result from drainage and irrigation. The resulting intensive use of suitable lands permits retirement or protected use of lands less suited for cultivation.

Benefits of watershed protection and flood prevention may be classified as onsite and offsite. The first includes benefits that result on lands where measures are installed.

Land treatment includes measures such as terraces, contour farming, stripcropping, rotations, pasture improvement, range management, land-use adjustments, control of wildfire, and tree planting. Adjustment in land use is often necessary for watershed protection; and while net farm incomes may be temporarily reduced during the

years of adjustment, incomes increase substantially once the new farming systems are in full operation.

Onsite benefits include the saving of soil resources from sheet and gully erosion, and conservation of moisture through increased water-holding capacity of the soil and increased rates of water infiltration. These benefits are reflected in increased productivity, higher recharge of underground water supply, and regulated return flows to streams and springs.

Land-treatment measures also result in offsite benefits through stabilization of streamflow and reduction of flood damages. It is mainly because of these offsite influences that so much interest in watershed protection is expressed by civic groups and local governments, and farmers who till bottom lands.

The larger part of the offsite benefits of watershed protection usually is obtained from measures that retard floodwater and improve stream channels. Such measures include floodwater-retarding structures, floodways, levees and dikes, sediment-collecting basins, and gully stabilizers. The maximum effectiveness and useful life of such measures depend on application and maintenance of land-treatment practices above the structures.

Flood prevention measures provide many upstream benefits. They protect cropland and pasture from floodwater damage and prevent damages to other farm property such as livestock, buildings, fences, roads, stored crops, and equipment. Community and other nonfarm properties and facilities of many types are protected, including roads, bridges, railroads, powerlines, and utilities.

Prevention of scour and streambank erosion, although constituting only a small percentage of the agricultural benefits, is important because it helps to maintain the productive capacity of flood-plain lands. Unprotected land in the flood plains of many headwater streams is idle, or limited to use as low-yielding pasture and meadows, because of the hazard of frequent floods, swamping, poor drainage, sediment deposition, and scour. Flood-plain lands generally have a high production potential, and flood protection enables farmers to use these lands for high-value crops.

Control of runoff water and flood prevention also create benefits through the prevention of sediment deposition on flood-plain lands, in streams, irrigation canals, reservoirs, and lakes, and through the improvement of water quality. Other benefits arise through the prevention of erosion of streambank channels and roadsides.

A number of indirect benefits likewise accrue from flood prevention, such as prevention of delays and rerouting of traffic, loss of business, and cost of caring for flood victims. Still other benefits, such as protection of life or prevention of illness by elimination of disease and health hazards, are difficult to evaluate in monetary terms. Maintenance and expansion of the productive capacity of watershed resources have other favorable impacts on surrounding communities. For example, greater stability in their operations is assured to processors and handlers of agricultural products.

The Department's programs often include fish and wildlife habitat development and may also result in pollution abatement and greater use of land and water resources for recreation. Also, the control of saltcedars and other useless phreatophytes results in a saving of water for beneficial uses for agriculture and other needs.

Under the Department's programs, numerous small towns and cities are taking advantage of the opportunity to include storage capacity for municipal and industrial water as a part of multiple-purpose developments. In addition to the benefits from having an adequate supply of municipal and industrial water, such projects result in substantial savings in costs, both to the municipality and to the Federal Government.

The benefits accruing in these 160 watersheds are listed in order of importance:

(1) Flood prevention.
(2) Drainage.
(3) Irrigation.
(4) Recreation and wildlife improvement.
(5) Municipal and industrial water development.

As required by law, funds will be spent only on projects that have a favorable benefit-cost ratio. Based on experience with the watershed program to date, farmers and local organizations (including local and State units of government) will contribute an estimated 45 percent of the total project cost.

A detailed summary of 160 watershed projects shows that the benefits of all measures greatly exceed the costs. The average benefits from structural measures alone are expected to be about $2 for each dollar of cost. These are direct monetary returns only. Other important benefits were not measured in dollars and cents.

Effect of Agricultural Programs on Water Quality

Sediment

The effects of the Department's programs on the quality of water will vary greatly from basin to basin. In areas where the source of sediment is upland fields and forests, conservation programs are very effective in reducing sediment production, especially if these areas are under intensive use. On the dry range and inherently poor forest lands of the arid and semiarid regions, weather and climatic conditions place a limit upon the amount of protective vegetation which can be supported. Here, conservation measures will have their greatest beneficial effects in normal or near-normal years.

In areas where stream channels are steep, and in arid or semiarid areas, the primary source of sediment may be from the channel, and the sediment may be coarser-grained material transported as "bed load." The concentration of bed load is controlled by the particle-size distribution of the sediment and the energy of the stream. Upland conservation measures have their greatest effect on channel erosion and bed load by reducing the rate of runoff.

Structural measures may or may not be effective in reducing sedimentation, depending upon their purpose and design, and upon the character of the channel sediment. Structures providing storage are about 90 percent effective in removing all types of sediment from streams. Therefore, downstream water quality is greatly influenced by the percent of the watershed area which is behind water-holding or water-retarding structures.

The total overall reduction of sediment production depends upon the existing sources of sediment; the nature, area of application, and degree of maintenance of land-treatment measures; and the area controlled by structural measures. Estimated reductions of sediment load are based on extrapolation of programs of the present level of intensity to 80 percent of the watersheds currently feasible of treatment in each of the major water resource regions. If a higher degree of control of watershed areas or intensity of treatment is attained in the future, higher percentages of reductions of sediment loads will result. The following table lists the major factors which influence sedimentation, and estimates the effects of the Department's programs on sediment in streams.

Table 12.—*Factors influencing sediment estimates*

Basin	Predominant physical characteristics				Sediment concentration		
	Climatic type	Land form	Relative erodibility of soils	Major erosion source of sediment	Present relative rate	Estimated reduction [1]	
						By 1980	By 2000
						Percent	*Percent*
New England	Humid	Rolling	Low	Sheet	Very low	6	10
Delaware-Hudson	do	do	do	do	Low	6	10
Chesapeake Bay	do	Rolling to dissected	do	do	Medium	21	35
Southeast	do	Dissected to low rolling	High	Sheet, channel	High	36	60
Eastern Great Lakes	do	Rolling	Low	Sheet	Low	6	10
Western Great Lakes	do	do	do	do	do	6	10
Ohio	do	do	Medium	do	Medium	12	20
Cumberland	do	Dissected	High	do	Low	6	10
Tennessee	do	do	do	do	do	6	10
Upper Mississippi	Humid to subhumid	Low rolling to dissected	High to low	do	High	21	35
Lower Mississippi	Humid	Dissected to low rolling	High	Sheet, channel	Very high	30	50
Lower Missouri	do	do	do	Sheet	do	24	40
Lower Arkansas, White, Red	do	do	Medium	do	High	33	55
Upper Missouri	Subhumid to semiarid	Low rolling to mountainous	High to low	Sheet, channel	High to low	33	55
Upper Arkansas, White, Red	Subhumid	Rolling	High	do	High	45	75
Western Gulf	Subhumid to semiarid	do	do	Sheet	do	30	50
Rio Grande-Pecos	Semiarid to arid	Dissected	Medium	Channel	do	21	35
Colorado	do	Dissected to mountainous	High to low	do	do	18	30
Great Basin	Arid	Mountainous to plains	Medium	Channel, sheet	Medium	12	20
Pacific Northwest	Superhumid to arid	Mountainous	Low to high	Sheet, channel	Low to high	9	15
Central Pacific	do	do	do	Channel, sheet	Medium	18	30
Southern Pacific	Subhumid to arid	do	do	do	do	18	30

[1] Based on physical characteristics shown in this table plus projected land use and treatment shown in tables 1, 2, 3, and 4, and estimated structures shown in table 5.

Chemical pesticides and fertilizers

The volume of chemical insecticides, herbicides, and other pesticides which are now being used is extremely small compared with the total water yield in the United States. In 1938, about 574 million pounds were used, but their use is rising rapidly. To date, except in a relatively few isolated cases, concentrations found in major rivers such as the Missouri, Mississippi, and Columbia are low, ranging from 5 to 20 parts per billion. The experience of the Department of Agriculture with insecticides has shown that, in spite of precautions, these materials occasionally get into smaller streams and lakes, and that they have caused some losses to fish and the aquatic insect life on which fish feed.

Because of the anticipated increase in demand for agricultural products by the year 2000, it is reasonable to expect an increase in the need for pesticides. Although there is now some effort being made to measure stream contamination, additional research is needed to prevent a serious situation from developing. It is possible that the development of biological methods of pest control may reduce the need for chemical pesticides.

It is also conceivable that the expected increase in the use of chemical fertilizers may perceptibly increase the concentration of nitrates, which are very soluble and easily leached. However, it is not expected that they will be concentrated to the point of becoming deleterious.

Reuse of irrigation water

As irrigation water is successively reclaimed and reused, its chemical quality decreases steadily, because of continual leaching of salts with each reuse. For this reason, the expected increase in the total amount of irrigation would tend to have a detrimental effect on the quality of water. However, this threat may be partially offset by more efficient means of transmitting water and closer control of applied water to prevent irrigation waste, which is now the source of most reused water.

In closed ground-water basins, where a significant portion of recharge to an aquifer is derived from irrigation water pumped from the aquifer, the chemical or mineral content of the water may eventually be materially increased. As in the case of reused surface water, control of transmission losses and water application so as to keep recirculation of water to a minimum will be effective in reducing the deterioration of ground-water quality.

Relation of Agricultural Programs to Other Water Developments

The Department of Agriculture recognizes the basic fact that the conservation, management, and use of our water resources is dependent upon the sound management, conservation, and use of our land, and that both are essential if we are to continue as a prosperous Nation. As pointed out in the 1950 report of the President's Water Resources Policy Commission –

> Floods cannot be controlled by building higher and higher levees, or permanently by building dams, if other things are neglected. The big streams are fed by small streams, and water control inevitably leads us back to the proper conservation of forests and agricultural land.

Coordination for water-use developments

The projected changes in agriculture to meet the increased future demand for food and fiber will involve some increased use of water. As shown in tables 1 and 3, about 63,350,000 acres of additional cropland will be needed by the year 2000. Also, as shown in table 5, a total of some 2,500,000 structural measures will be needed by the year 2000. These two aspects of agricultural programs, together with land-treatment measures for the conservation, management, and use of our land and water resources, constitute the biggest remaining job to be done in the water conservation and development field. Because of the extensive land area involved, the accomplishment of this task will provide benefits to a large segment of the population of the United States.

Land-treatment measures which lead to increased production and soil stability will result in some increase in water use. As indicated in table 7, this added water requirement is minor relative to total water yield, and is more than justified by the potential for not only sustaining but increasing production of agricultural products, improving streamflow patterns, and reducing sediment and floodwater damage. Quantitatively, these reductions are well within the

error inherent in the design of larger water-supply projects, and therefore will not significantly affect other water developments.

Evaporation, seepage, and use of water (shown in table 8) resulting from installing structural measures are an insignificant amount of the total water supply, and therefore will not materially affect other water developments. Although reductions of evaporation losses from these small reservoirs are possible, it is believed that efforts to reduce these losses will be made only in extremely critical areas by the year 2000.

Agriculture's additional need for irrigation water could be partially offset by improvements designed specifically to reduce waste in water transmission, application, and reuse. The anticipated effects of improved irrigation practices have been considered in the estimates of irrigation water needs presented in table 9. These water requirements are significant in some water resource regions and will reduce the water supply to downstream projects. The effect of future irrigation on downstream water yield in some regions is of a magnitude that requires its consideration in other water developments.

Certain features of the agricultural programs, however, will provide distinct benefits to downstream water-supply projects. The influence of structural and land-treatment programs upon water yield will result in the beneficial conversion of some surface runoff to subsurface flow, or to groundwater storage. However, the degree to which these conversions are attained will depend upon the soils, geology, and climate of individual watersheds. The Department is exploring the possibilities of this concept as it affects watershed management for water supply.

Reductions of sediment by means of soil and water conservation programs, estimated in table 12, will prolong the useful life and increase the operating efficiency of water-supply facilities downstream. Reductions in flood hazard and the general stabilizing effects on streamflow by structural, agronomic, and forestry measures favorably affect the economics and feasibility of water-supply developments at many locations.

Coordination for flood control

In recent years national flood control policy has received increased attention and implementation which directs a coordinated approach toward flood control. However, this policy has not been fully implemented in all needed phases of work. There is urgent need for more flood-damage prevention through a functionally interrelated threefold program, with each part given proper weight in terms of public assistance and coordinated with the others to the fullest degree possible. These are:

(1) *Land treatment.*—Land treatment includes such measures as contour cultivation, terracing, improved rotations, cover crops, reforestation, control of wildfire, and improved management of range, woodland, and forest lands. These measures, in proper combination, help prevent erosion, reduce flood peaks, maintain soil fertility, conserve water by storing it in the soil, prevent damage from the erosive action of rainfall and runoff, and reduce the sediment loads of creeks and rivers. Land-treatment measures are already being installed by private landowners and on public lands over which the Department has jurisdiction, under the various programs of the Department of Agriculture, which includes research, technical assistance, educational assistance, and direct financial aids.

(2) *Upstream waterflow retardation and channel stabilization.*—This phase of watershed improvement, involving work on the tributaries and smaller waterways to control or retard runoff, includes measures such as small floodwater-retarding structures, gully stabilization works, and channel improvements. These measures are installed to alleviate floodwater and sediment damage in the smaller watersheds above the major downstream works. Such measures also retard runoff and stabilize sources of sediment in upstream channels. This type of work is carried out in watersheds by local organizations, with financial and technical assistance from the Department of Agriculture. They supplement water-control measures ordinarily installed by farmers and ranchers.

(3) *Downstream flood-control measures.*—Large reservoirs and levees constructed on the main waterways control floodflows in the large river valleys. Such measures alleviate urban and agricultural damages caused by major floods on the lower reaches of the big rivers. This work is the responsibility of the Corps of Engineers.

This three-phase program is a coordinated approach to flood prevention and control—a program that protects the uplands as well as the lowlands, and the small upstream communities as well as the downstream cities.

Meeting Needs of Agricultural Services and Activities Affecting Water

In the full development of water resources in our major river basins, the Department believes that its programs for upstream soil and water conservation and flood prevention are a logical prerequisite to other types of water conservation and development programs. This position was supported in hearings held by the House Agriculture Committee in the Midwest in 1951. The committee reached these conclusions:

> First, programs for soil and water conservation and downstream river development are closely related, but a serious shortcoming existed in our attack on the problem.
>
> Second, the shortcoming lay in a lack of purposeful activity in small watersheds. A gap existed between programs to conserve soil and water on individual farms and big developments on major rivers.
>
> Third, the work in small watersheds can proceed without waiting on major river structures * * * .

Our rapidly growing population progressively increases its demands upon agriculture. As experienced during war periods, increased demands for agricultural products posed problems of land-use conversions which sometimes exploited our soils. Population growth could cause similar exploitation unless the agricultural services and activities are facilitated, in accordance with such growth, in the acquisition of technical knowledge and in the establishment of the proper measures on the land to keep abreast of these changing demands.

Greater emphasis should be placed on programs and activities to conserve and improve cultivated lands, forests, and rangelands as a means of protecting and enhancing the water resource.

More specific requirements to meet these growing needs are:

(*a*) *Acceleration of soil and water conservation on farms and ranches.*—Intensify programs of assistance to farmers and ranchers to help them use and treat their land to reduce erosion and the rate of runoff, and to increase the efficiency of use and transmission of irrigation water.

(*b*) *Better management of forest lands.*—Facilitate programs for the prevention of overcutting, destructive logging methods, overgrazing of forests, and carelessness with fire. These are still too prevalent as common practices on large acreages of forest lands—and thus substantially reduce the effectiveness of forests as protectors of water supplies. Accelerate reforestation and other constructive forest conservation activities.

(*c*) *Improvement of vegetative cover on rangelands, including better management of grazing.*—Use of ranges by livestock and game should conform to standards which will maintain satisfactory watershed cover. Revegetation should be undertaken promptly where cover is badly deteriorated.

(*d*) *Increased assistance to local organizations for watershed protection and flood prevention.*—This phase of the three-phase program to achieve a coordinated approach to flood prevention and control is lagging behind the other two phases and needs to be accelerated to meet the needs of local organizations requesting assistance to solve the water problems of their watersheds.

(*e*) *Control of phreatophytes.*—Nonbeneficial, high water-using species, such as saltcedar growing along water courses in the Southwest, should be held in check. At the same time, water used by vegetation that prevents erosion or harmful sediment movement should be recognized as an essential use.

(*f*) *Acceleration of research.*—Acceleration of the agricultural and forestry research programs, particularly those dealing with the physical and economic aspects of agricultural water supply and use, is essential to provide information which will permit agriculture to meet the demands for food and fiber without damage to our natural resources. Specifically, there is an urgent need to increase our knowledge of the hydrology of forest and agricultural watersheds as affected by different intensities, types, and techniques of use, in order to develop comprehensive water programs. For further details, see the U.S. Department of Agriculture's report to the Senate Select Committee on National Water Resources, entitled "Research Needs in Water Resources." [5]

(*g*) *Educational, technical, and financial assistance.*—In order to fully implement the items listed above, there is need to provide adequate education for the public. There is also need to provide

[5] Committee Print No. 28.

technical and financial assistance to landowners in certain aspects of conservation.

Assumptions and Methods Used in Preparing Estimates

Water yield of any area is derived from precipitation. In general, water from precipitation is disposed of through the natural processes of interception by vegetation, direct evaporation, transpiration, surface runoff, and infiltration. Water yield is composed of varying amounts of surface runoff and that portion of infiltrated water which is not tied up as soil moisture and groundwater recharge. The latter portion is generally referred to as return flow or subsurface runoff.

The amount and intensities of precipitation cannot yet be manipulated by men. However, the processes of onsite surface runoff and infiltration can be manipulated by men. Such practices as establishing a dense land cover, contour furrowing, striperopping, water spreading, etc., tend to increase the infiltration potential and thus decrease onsite surface runoff.

The effects of departmental and similar programs on total water yield thus in essence require an evaluation of the disposition of onsite infiltrated water. Part of the infiltrated water is required for soil moisture recharge. This requirement reflects moisture depletions by direct evaporation to the atmosphere and transpiration by plants, or evapotranspiration. After soil moisture is replenished to field capacity, additional accretions percolate to ground water. In many areas, all or some fraction of this water is eventually available as streamflow at some downstream point.

Water flowing in stream and river channels is subject to depletion by evaporation from the water surface, transpiration by phreatophytes, seepage into local unsaturated aquifers, and diversions for use. At some point in a stream system the depletions balance the accretions to flow, and the water yield per unit of drainage area is at a maximum for that watershed. Figure 3 illustrates this phenomenon in the Ohio River Basin. Tables 10 and 11 show the average annual water yield for the United States for drainage areas of 0.1 and 1,000 square miles. The water yield at 0.1 square mile is considered to be onsite or that available for onfarm impoundment. The water yield at 1,000 square miles is considered to be that available to downstream users.

Onsite water yields are dependent primarily upon the climate, although they can be influenced to some extent by man. Experimental data collected at agricultural and forest research stations indicate that soil and water conservation practices influence the magnitude of the component of the precipitation that enters the soil in the dry subhumid, moist subhumid, and humid climatic regions. The answer is not so clear for the semiarid and arid climatic region, where the average annual onsite water yield may be as low as 2 acre-feet per square mile, or for the superhumid region where the yield may be 4,000 acre-feet per square mile.

In the semiarid and arid regions the quantity of vegetation is dependent to a large extent upon the rainfall. By proper range and pasture management, man can increase the quality of the forage plants. This does not mean that additional water will be used, because when the evapotranspiration potential greatly exceeds the supply provided by precipitation, any type of vegetation will use all the available water. The isogram map (fig. 4) is a graphic representation of the magnitude by which potential evapotranspiration (fig. 5) exceeds the available supply (fig. 6). The available supply (precipitation retained, fig. 6) was developed from figures 7 and 8. If a greater portion of the precipitation could be made to infiltrate the soil, certainly much of it would be used by the vegetation. Since these regions are primarily rangeland, significant increases in infiltration will depend largely upon the construction of contour furrows, water-spreading dikes, and retention terraces—expensive practices that are not now, and not likely to become, widespread.

In the superhumid climatic region, precipitation exceeds evapotranspiration, and there is seldom a water shortage within the soil profile. The amount of the precipitation that infiltrates the soil may be increased by conservation practices. Infiltrated water raises the soil moisture above field capacity,

and most of the excess appears downstream as an accretion to streamflow from subsurface flow and shallow aquifers.

In the dry subhumid, moist subhumid, and humid climatic regions the evapotranspiration potential exceeds the supply during some seasons and falls below it in others. It is in these regions that additional water induced by conservation practices to infiltrate the soil during the dry season will be most beneficial to crop production and will have the greatest effect upon the streamflow. Accretions to soil moisture during the wet seasons and during seasons of low evapotranspiration will have a minor effect on water yield, because soil moisture deficiencies and groundwater depletions have been satisfied. Computations of the average annual effect of conservation practices on water yield must consider the combined effect for all seasons.

The values of present onsite water yield shown in table 10 were computed by averaging the onsite average annual water yield data collected by the Agricultural Research Service within a water resource region and correlating them with average annual water yields reported by the U.S. Geological Survey. The computations were made on the basis of a composite unit area on which the land utilization and conservation treatment were distributed as the average for the region shown in table 1, and received precipitation equal to the average for the region. The onsite water yield for 1980 and 2000 was computed by utilizing present amounts of runoff for each use and treatment, and applying the land treatment and land use estimated for 1980 and 2000 (tables 2, 3, and 4).

Downstream water yield by regions

Downstream water yield is composed of varying amounts of onsite water yield which appear as surface runoff, and subsurface and ground-water flow. Based on the composite unit areas for the water resource regions, this is an increasing quantity in a downstream direction until the depletions balance the accretions. This usually occurs at some value between 10 and 1,000 square miles of drainage area. Thereafter depletions exceed accretions and the yield per unit of drainage area decreases.

To determine the relationship of downstream water yield to drainage area for each of the water resource regions, composite watersheds were developed for selected ranges in drainage area size. The mean of the drainage areas of the U.S. Geological Survey stream gages within each size range was taken as the composite drainage area for the size range. The mean of the average annual water yield reported for the stream gages within the range was taken as the composite water yield. The ranges selected were 1 to 10; 10 to 100; 100 to 1,000; 1,000 to 10,000; and 10,000 to 100,000 square miles. Agricultural Research Service data were used to compute composite drainage areas for ranges of 0.001 to 0.01; 0.01 to 0.1; and 0.1 to 1 square mile. The means for each range were plotted on log-log plotting paper and a smooth curve drawn. The water yield per unit of drainage area was read from the curves for 0.1 square mile, at the point of maximum yield, and at 1,000 square miles. The data for 0.1 and 1,000 square miles are tabulated in tables 13 and 14 under the column headings, "Present onsite runoff (Q_o)" and "Present downstream water yield (Q_d)". Since these values are based on a composite watershed unit area, they are not applicable to any specific area of comparable size in the watershed.

The computations for the average annual downstream water yield for 1980 and 2000 were based upon the following assumptions:

(*a*) Future accretions to soil moisture will be divided between onsite use by evapotranspiration and downstream accretions to flow in the same proportions as the present soil moisture is divided.

(*b*) That additional water used onsite by evapotranspiration and the increase in use, seepage, and net evaporation from ponds and reservoirs would have been subject to the same proportional losses that are now occurring downstream from the point of maximum yield.

(*c*) The net depletion from ponds and reservoirs is equal to the evaporation from the average annual surface area, minus the rainfall on the average annual surface area, plus the runoff that would have occurred from the area covered by water if the pond or reservoir had not been constructed.

The following equations were developed from the above assumptions and used in tables 13 and

Computations of the Effect of Agricultural

Table

No	Water Resources Region	Area	Average Precipitation		Present Onsite Runoff (0.10 Sq. Mi.)	Present Runoff at Point of Max. Yield	Present Down Stream Water Yield (1000 Sq. Mi.)	Increase In			
								Onsite Infiltration due to Land Treatment	Average Surface Area of Ponds — Res	Net Evaporation Depletion from Ponds, Other Reservoirs and Watershed Structures	
		Sq. Mile	Inches	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac./sq. Mi.	Inches	Ac. ft./sq. Mi.
				P	Q_o	Q_m	Q_d	V_{LT}	A	L	V_e
	EASTERN										
1	New England	58871	41.50	2250.0	1000.0	1280.0	1250.0	10.0	.3645	6.56	.1995
2	Delaware-Hudson	39012	43.20	2306.0	980.0	1580.0	1560.0	- 8.2	.6580	11.48	.6295
3	Chesapeake Bay	64836	41.01	2187.2	950.0	940.0	940.0	0.9	.8236	7.65	.5288
4	Southeast	267790	52.67	3809.0	170.0	940.0	960.0	- 0.1	.8629	6.33	.4552
5	Eastern Great Lakes	67746	34.50	1740.0	410.0	920.0	900	2.8	.3945	8.48	.2675
6	Western Great Lakes	90659	35.28	1746.1	260.0	630.0	600.0	0.6	.1735	9.43	.1409
7	Ohio	194525	41.84	2220.8	500.0	980.0	980.0	0.7	.7442	5.59	.3467
8	Cumberland	21748	48.44	2578.7	460.0	1510.0	1500.0	5.2	.9775	6.51	.5502
9	Tennessee	40168	50.50	2685.7	410.0	1480.0	1380.0	1.5	1.1686	4.26	.4169
10	Upper Mississippi	190767	34.46	1849.1	200.0	620.0	620.0	0.6	.5291	2.97	.2734
11	Lower Mississippi	78466	54.09	2891.4	400.0	1220.0	1020.0	1.1	.4635	9.73	.7812
12	Lower Missouri	69428	34.45	1836.5	250.0	715.0	600.0	1.2	.8058	13.29	.8902
13	Lower Ark., White, Red	112200	44.50	2373.5	520.0	960.0	760.0	0.1	1.1202	16.01	1.4945
	WESTERN										
14	Upper Missouri	500634	17.15	914.7	120.0	162.0	108.0	1.5	.1345	25.65	.5826
15	Upper Arkansas - Red	170515	22.65	1208.0	57.0	540.0	160.0	0.2	.5076	59.25	1.6605
16	Western Gulf	189430	30.99	1652.8	210.0	550.0	305.0	- 0.8	.5809	55.02	1.5984
17	Upper Rio Grande - Pecos	137810	14.21	757.9	15.0	290.0	135.0	0.4	.0179	51.18	.3295
18	Colorado	245518	10.71	571.2	28.0	390.0	160.0	0.8	.0525	45.49	.998
19	Great Basin	174648	9.49	505.5	12.0	300.0	50.0	0.2	.0268	56.00	.08
20	Pacific Northwest	246611	23.19	1236.8	54.0	730.0	550.0	0.8	.1162	17.52	.1677
21	Central Pacific	103564	25.65	1357.3	110.0	800.0	640.0	0.6	.1898	30.99	.6902
22	South Pacific	41025	10.15	541.3	98.0	290.0	55.0	- 0.7	.1715	57.69	.8245

14 to compute the downstream water yield for 1980 and 2000:

$$V = P - Q_o$$

$$V_a = Q_m - Q_o$$

$$V_m = V_{LT} - \frac{V_a \times V_{LT}}{V}$$

$$V_{id} = \frac{V_m Q_d}{Q_m}$$

$$V_e = \frac{AL}{12}$$

$$V_i = V_e + U + S_m$$

$$V_{sd} = \frac{V_i Q_d}{Q_m}$$

$$V_d = V_{id} + V_{sd} + V_i$$

$$Q'_o = Q_o - V_{LT}$$

$$Q'_d = Q_d - V_d$$

In which:

P = Average annual precipitation, acre-feet/square mile.

Q_o = Present average annual onsite runoff, acre-feet/square mile.

V = Volume of average annual precipitation left on the watershed, onsite, acre-feet/square mile.

Q_m = Present average annual runoff at point of maximum yield, acre-feet/square mile.

V_a = Average annual accretion to streamflow at point of maximum yield, acre-feet/square mile.

V_{LT} = Average annual onsite increase in infiltration due to land treatment (1980 or 2000), acre-feet/square mile.

Programs on Average Annual Water Yield—1980

13

Increase in Consp. Use from Ponds and Reservoirs	Increase in Consp. Seepage from Ponds and Reservoirs	$S-\left(\frac{V_m S}{V}\right)$	V_s+U+S_m	$P-Q_o$	Q_m-Q_o	$V_{LT}-\left(\frac{V_s V_{LT}}{V}\right)$	$\frac{V_m Q_d}{Q_m}$	$\frac{V_s Q_d}{Q_m}$	Increase in irrigation use	$V_{sd}+V_{ld}+V_i$	Q_o-V_{LT}	Q_d-V_d
Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.
U	S	S_m	V_s	V	V_o	V_m	V_{md}	V_{sd}	V_i	V_d	Q_o	Q_d
.4571	.5602	.4250	1.0816	1160.0	280.0	7.59	7.41	1.06	0.41	8.88	990.0	1241.1
.5115	.6402	.5115	1.6521	1724.0	800.0	- 4.40	- 4.40	1.65	1.03	- 1.72	588.2	1381.7
.6088	1.0752	.7884	1.9261	1837.2	490.0	0.66	0.66	1.93	0.69	3.28	349.1	836.7
.6977	1.3780	.9759	2.1288	2639.0	770.0	- 0.07	- 0.07	2.13	1.24	5.30	170.1	936.7
.6646	.8048	.5178	1.4469	1450.0	310.0	1.80	1.76	1.42	0.15	3.33	407.2	896.7
.0946	.5444	.2070	.4407	1200.0	490.0	0.40	0.39	0.39	0.51	1.25	259.4	598.8
1.0014	1.4630	.8791	2.2272	1720.8	520.0	0.53	0.53	2.23	0.37	3.13	499.3	916.9
1.8277	1.8091	1.0855	3.4412	2118.7	850.0	1.92	1.91	3.41	0.06	5.38	456.8	1294.6
1.1714	2.0978	1.1103	3.6996	2273.7	1070.0	0.79	0.74	2.52	0.29	5.55	408.5	1376.4
.4476	.6652	.4794	1.2004	1449.1	220.0	0.51	0.51	1.20	0.35	2.06	199.4	417.9
.8105	.5638	.6435	2.2350	2431.4	640.0	0.82	0.82	2.24	2.70	5.76	398.9	1014.2
.6108	1.0780	.9052	2.4042	1586.3	165.0	1.08	1.04	2.32	0.30	3.66	248.8	396.3
.6903	1.2256	.9055	3.0881	2053.3	540.0	0.07	0.06	2.73	0.81	3.60	519.9	756.4
.2267	.3702	.3506	.9599	794.7	42.0	1.23	0.82	0.64	- 2.34	- 0.88	116.7	108.9
.4913	.6766	.5015	2.6531	1171.0	303.0	0.15	0.07	1.25	- 1.17	0.15	36.8	159.8
.5458	.7712	.5994	2.7456	1442.8	320.0	- 0.62	- 0.36	1.58	- 3.78	- 2.56	210.8	507.6
.2311	.4943	.3117	1.4721	741.9	274.0	0.25	0.12	0.69	- 1.44	- 0.63	15.6	135.6
.0761	.1210	.0404	.3157	543.2	362.0	0.27	0.11	0.15	- 8.93	- 8.69	27.2	163.7
.0371	.0616	.0270	.1447	513.3	288.0	0.09	0.02	0.02	- 9.93	- 9.89	11.8	59.9
.0501	.2081	.0787	.2965	1182.8	736.0	0.30	0.21	0.21	- 9.34	- 8.92	53.2	558.9
.0658	.3635	.1624	.7184	1247.3	690.0	0.27	0.22	0.57	-12.93	-12.14	109.4	652.1
.0758	.3376	.1686	1.0689	503.3	252.	- 0.35	- 0.04	0.13	-12.26	-12.17	58.7	47.2

V_m = Average annual depletion in water yield at point of maximum yield, due to land treatment (1980 or 2000), acre-feet/square mile.

Q_d = Present average annual downstream (1,000 square miles) water yield, acre-feet/square mile.

V_{md} = Average annual downstream (1,000 square miles) depletion in water yield due to land treatment (1980 or 2000), acre-feet/square mile.

V_e = Increase in net depletion due to evaporation and loss of runoff from pond and reservoir areas (1980 or 2000), acre-feet/square mile.

A = Increase in average surface area of ponds and reservoirs, acre-feet/square mile.

L = Increase in average annual net loss from ponds and reservoirs, inches.

U = Increase in average annual domestic use of water from ponds and reservoirs (1980 or 2000), acre-feet/square mile.

S = Average annual onsite seepage from stock ponds and other reservoirs, acre-feet/square mile.

S_m = Average annual depletion in water yield at point of maximum yield, due to seepage from stock ponds and other reservoirs, acre-feet/square mile.

Computations of the Effect of Agricultural

Table

No	Water Resources Region	Area	Average Precipitation		Present Onsite Runoff (0.10 Sq. Mi.)	Present Runoff at Point of Max. Yield	Present Down Stream Water Yield (1000 Sq. Mi.)	Increase In			
								Onsite Infiltration due to Land Treatment	Average Surface Area of Ponds -- Res	Net Evaporation Depletion from Ponds, Other Reservoirs and Watershed Structures	
		Sq. Mile	Inches	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac./sq. Mi.	Inches	Ac. ft./sq. Mi.
				P	Q_o	Q_m	Q_d	V_{LT}	A	L	V_e
	EASTERN										
1	New England	58270	40.50	2160.0	1000.0	1280.0	1250.0	10.8	.5949	6.56	.3252
2	Delaware-Hudson	35012	43.20	2304.0	580.0	1580.0	1580.0	-15.8	1.1150	11.48	1.0667
3	Chesapeake Bay	63828	41.01	2187.2	350.0	840.0	840.0	- 1.7	1.3640	7.65	.8696
4	Southeast	265750	52.57	2809.0	170.0	940.0	940.0	1.0	1.3650	6.53	.7201
5	Eastern Great Lakes	47540	54.50	1840.0	410.0	920.0	900.0	- 2.5	.9864	8.14	.4049
6	Western Great Lakes	86639	28.99	1546.1	260.0	680.0	600.0	1.5	.2851	9.41	.2240
7	Ohio	142239	41.64	2220.8	500.0	920.0	920.0	1.5	1.2537	5.59	.5840
8	Cumberland	17490	48.55	2578.7	460.0	1510.0	1500.0	5.4	1.5319	6.51	.8311
9	Tennessee	40660	50.30	2685.7	410.0	1480.0	1580.0	7.6	1.7947	4.28	.6401
10	Upper Mississippi	186807	30.90	1649.1	200.0	420.0	420.0	2.1	.5441	9.97	.4521
11	Lower Mississippi	60444	55.09	2951.4	400.0	1020.0	1020.0	3.2	1.8044	9.75	1.4631
12	Lower Missouri	53400	44.45	1856.5	250.0	415.0	400.0	1.8	1.3598	13.29	1.5053
13	Lower Ark., White, Red	110400	44.50	2375.1	520.0	860.0	760.0	5.7	2.0205	16.01	2.6957
	WESTERN										
14	Upper Missouri	504694	17.15	914.7	120.0	160.0	100.0	3.9	.2894	23.63	.5699
15	Upper Arkansas - Red	170515	22.65	1208.0	51.0	540.0	160.0	0.6	.8764	59.25	2.8666
16	Western Gulf	189200	30.99	1652.8	210.0	530.0	505.0	2.1	.9318	33.02	2.5640
17	Upper Rio Grande - Pecos	157810	14.21	757.9	16.0	290.0	135.0	0.7	.2968	51.18	1.2659
18	Colorado	345518	10.71	571.1	28.0	390.0	160.0	1.5	.0935	45.49	.3535
19	Great Basin	174648	9.85	525.5	12.0	300.0	50.0	0.5	.0450	56.90	.1556
20	Pacific Northwest	246411	25.19	1256.8	54.0	790.0	556.0	1.8	.1783	17.32	.2575
21	Central Pacific	103564	25.45	1357.2	110.0	800.0	640.0	0.5	.2849	30.99	.7358
22	South Pacific	41003	10.15	541.3	38.0	290.0	32.0	- 1.7	.2408	57.69	1.1576

V_s = Total depletion of average annual water yield at point of maximum yield due to structures (1980 or 2000), acre-feet/square mile.

V_{sd} = Average annual downstream (1,000 square miles) depletion in water yield due to structures (1980 or 2000), acre-feet/square mile.

V_d = Total average annual downstream (1,000 square miles) depletion in water yield due to the U.S. Department of Agriculture's and similar programs (1980 or 2000), acre-feet/square mile.

V_i = Average annual increase in water used for irrigation, acre-feet/square mile.

Q_o' = Average annual onsite water yield in 1980 or 2000, acre-feet/square mile.

Q_d' = Average annual downstream (1,000 square miles) water yield, 1980 or 2000, acre-feet/square mile.

Land treatment

Utilizing Agricultural Research Service data and rainfall-runoff relationships contained in the National Soil Conservation Service Engineering Handbook (sec. 4, supp. A), the relationship of runoff from untreated cultivated land to treated cultivated land, treated and untreated pasture

Programs on Average Annual Water Yield—2000

14

Increase in—Con.												
Use from Ponds and Reservoirs	Seepage from Ponds and Reservoirs	$S-\left(\frac{V_{sa}S}{V}\right)$	V_a+U+S_m	$P-Q_o$	Q_m-Q_o	$V_{LT}-\left(\frac{V_a V_{LT}}{V}\right)$	$\frac{V_a Q_a}{Q_m}$	$\frac{V_a Q_a}{Q_m}$	Increase in irrigation use	$V_{ua}+V_{sa}+V_i$	Q_o-V_{LT}	Q_o-V_a
Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.	Ac. ft./sq. Mi.
U	S	S_m	V_a	V	V_o	V_m	V_{ua}	V_{sa}	V_i	V_a	Q_o	Q_a
.6162	.7532	.5714	1.3128	1160.0	280.0	8.19	8.00	1.48	3.02	12.50	989.2	1237.5
.6958	1.3210	.7080	2.4705	1724.0	800.0	- 8.47	- 8.47	2.47	3.11	- 2.89	595.8	1382.9
.8491	1.4750	1.0816	2.8003	1837.2	490.0	- 1.25	- 1.25	2.80	16.90	18.45	351.7	821.6
.9168	1.7900	1.2677	2.9046	2639.0	770.0	0.71	0.71	2.90	13.74	17.35	169.0	982.6
.9128	1.0973	.7060	2.0237	1450.0	510.0	- 1.41	- 1.57	1.98	7.75	8.16	412.5	891.8
.1265	.4023	.2729	.6834	1286.0	420.0	1.01	0.89	0.55	9.01	10.45	258.5	589.6
1.5890	1.5985	1.2084	3.1814	1720.8	420.0	.98	.98	3.18	7.62	11.78	498.7	908.2
2.4931	2.4521	1.4684	4.7926	2118.7	850.0	3.23	3.20	4.75	4.06	12.01	454.6	1288.0
1.5321	2.7110	1.4352	3.6074	2273.7	1070.0	4.02	3.75	3.36	5.06	12.17	402.4	1367.8
.5970	.7488	.6351	1.6842	1449.1	220.0	1.78	1.78	1.68	13.82	17.28	197.9	400.1
1.1096	1.1669	.8693	3.4420	2431.4	620.0	2.38	2.38	3.44	11.05	16.87	396.8	1003.1
.8293	1.3576	1.2164	3.5510	1586.3	165.0	1.61	1.55	3.42	21.40	26.37	248.2	373.6
.9694	1.6387	1.2077	4.8728	2053.3	540.0	2.73	2.41	4.30	4.03	10.74	316.3	749.3
.2969	.4789	.4536	1.3204	794.7	42.0	3.69	2.46	0.88	7.86	11.20	116.1	96.8
.6785	.9020	.6686	4.2137	1171.0	305.0	0.44	0.81	1.98	0.29	2.48	36.4	157.5
.6984	.9737	.7577	4.0201	1442.8	320.0	1.65	0.94	2.31	3.57	6.82	207.9	298.2
.3008	.6354	.4007	1.9674	741.9	274.0	0.44	0.20	0.91	- 0.26	0.85	15.3	134.2
.1469	.2075	.0692	.5694	543.2	362.0	0.50	0.21	0.23	-10.20	- 9.76	26.5	169.8
.0689	.0990	.0435	.2474	513.3	288.0	0.22	0.04	0.04	-13.54	-13.46	11.5	63.5
.0890	.2673	.1010	.4473	1182.8	736.0	0.68	0.47	0.31	- 3.92	- 3.14	52.2	553.1
.1123	.4685	.2093	1.0574	1247.3	690.0	0.22	0.16	0.85	-15.61	-14.58	109.5	654.6
.1272	.4314	.2154	1.5002	503.3	252.0	- 0.85	- 0.10	0.18	-12.16	-12.08	39.7	47.1

and forest land, and from other land was computed for each water resource region.

The ratios were used to subdivide the total onsite runoff (Q_o in tables 13 and 14) into the amounts produced by each type of land use and treatment. This was done by using the relationship:

$$Q_{ua}A_{ua}=Q_{cu}A_{cu}+Q_{ct}A_{ct}+Q_{pu}A_{pu}+Q_{pt}A_{pt}+Q_{fu}A_{fu}+Q_{ft}A_{ft}+Q_mA_m$$

and:

$$Q_{ct}=Q_{cu}F_{ct}$$
$$Q_{pu}=Q_{cu}F_{pu}$$
$$Q_{pt}=Q_{cu}F_{pt}$$
$$Q_{fu}=Q_{cu}F_{fu}$$
$$Q_{ft}=Q_{cu}F_{ft}$$
$$Q_m=Q_{cu}F_m$$

Substituting:

$$Q_{ua}A_{ua}=Q_{cu}A_{cu}+Q_{cu}F_{ct}A_{ct}+Q_{cu}F_{pu}A_{pu}+Q_{cu}F_{pt}A_{pt}+Q_{cu}F_{fu}A_{fu}+Q_{cu}F_{ft}A_{ft}+Q_{cu}F_mA_m$$

Factoring and dividing:

$$Q_{cu}=\frac{Q_{ua}A_{ua}}{A_{cu}+F_{ct}A_{ct}+F_{pu}A_{pu}+F_{pt}A_{pt}+F_{fu}A_{fu}+F_{ft}A_{ft}+F_mA_m}$$

in which:

F_{cu}, F_{ct}, F_{pt}, F_{pu}, F_{fu}, F_{ft}, and F_m=the ratio of the runoff from treated and untreated cultivated, pasture, forest, and miscellaneous land to the runoff from cultivated, untreated land.

Q_{cu}, Q_{ct}, Q_{pu}, Q_{pt}, Q_{fu}, Q_{ft}, and Q_m=runoff in feet depth from treated and untreated cultivated, pasture, and forest land, and miscellaneous land.

A_{cu}, A_{ct}, A_{pu}, A_{pt}, A_{fu}, A_{ft}, and A_m=number of acres of treated and untreated cultivated, pasture, forest, and miscellaneous land in a composite square mile.

A_{uu}=acres per square mile (640).

Q_{uu}=average annual onsite runoff, feet depth.

The present runoff from each land-use and treatment area of the composite square mile is computed by multiplying Q_{cu} by the corresponding area and ratio. For example, the runoff from pasture untreated, Q_{pu}, is equal to $Q_{cu} \times A_{pu} \times F_{pu}$. The 1980 and 2000 runoff from each land-use and treatment area are found by substituting the 1980 and 2000 areas in the above computations. A simple summation and subtraction gives the accretion to soil moisture, V_{LT}, in tables 13 and 14, and is the onsite change in runoff per square mile resulting from land treatment. This is used in preparing table 10.

Although a percentage of this accretion returns as downstream water yield, the remainder (which is shown as a depletion to streamflow) cannot be considered a loss. Part may be utilized in crop production and part may be considered as a contribution to ground water.

Structural measures

Table 5 shows the numbers of structural measures and their maximum and average surface area for 1959, 1980, and 2000 by water resource regions. The summation of the average water-surface areas divided by the total area of the water resource regions gives the average evaporative surface area for the composite square mile for 1959, 1980, and 2000. The difference in the average surface area per square mile between 1959 and 1980 or 2000 is the increase in average surface area, A, in tables 13 and 14.

The increase in net loss from ponds and reservoirs, V_e, in tables 13 and 14 was computed by planimetering the isograms from the map of evaporation minus precipitation plus runoff that would have occurred from the pond area covered by water (fig. 9). The values, L, are shown as net loss from ponds and reservoirs, inches, in tables 13 and 14. The map was prepared from an isogram map of average annual runoff (fig. 7) and an isogram map of net evaporation from ponds and reservoirs (fig. 10). Figure 10 was developed from the map of the normal annual amount of precipitation (fig. 8) and average annual lake evaporation (fig. 11). Since figure 11 has not been widely distributed to date, figures 12 and 13 are included to show the supporting data.

The difference in the number of ponds and reservoirs in 1959 and 1980 or 2000 was expressed as number per square mile. The average annual use for domestic and livestock water per pond was estimated and multiplied by the number of ponds and reservoirs to obtain the average annual use, U, in tables 13 and 14 per composite square mile.

Seepage from farm ponds and other reservoirs has been estimated on the basis of the average water-surface area. Because of the improvement in construction methods and the increase in the use of special sealing materials, future average annual seepage has been estimated at 30 inches per year. Seepage from floodwater-retarding structures has been assumed to be offset by the reduction in seepage that normally occurs when large areas of flood-plain land are inundated. Although it is recognized that seepage will vary widely, an attempt has been made to evaluate average seepage on the basis of future construction practices.

Seepage has been considered in this report in order to evaluate its effect on streamflow. Although streamflow will be reduced, this reduction should not be considered a loss but rather a contribution to ground water. In many areas this will provide important benefits.

Irrigation

The change in volume of irrigation water that will be needed in 1980 and 2000 was obtained from table 9 and expressed as acre-feet per square mile, V_i, in tables 13 and 14. Irrigation water requirements were subtracted algebraically without modification from the present downstream yield. The values reflect more efficient transmission of irrigation water and more efficient use on the land, resulting from anticipated advances in technology. Further details on the irrigation estimate may be obtained from the Department's report in reply

to the letter of July 1, 1959, from the U.S. Senate Select Committee on National Water Resources.[6]

Other assumptions and considerations which may affect estimates

Evaporation from reservoirs.—The use of hexadecanol and octadecanol for evaporation suppression by the formation of monomolecular films is being studied by a number of agencies. The results of pan-evaporation studies are very encouraging; evaporation reductions of 33 to 60 percent have been obtained. Experiments carried out on small ponds by the Oklahoma State University and the Southwest Research Institute of San Antonio, Tex., have not been so encouraging. Mr. R. R. Cruse of the Institute reported a reduction of 18 percent in evaporation from a 3-acre pond near San Antonio during the period October 10–31, 1956. F. R. Crow and E. R. Daniel, associate professors of agricultural engineering, Oklahoma State University, reported reductions in evaporation of 4 to 5 percent from specially designed 0.3-acre ponds.

William C. Ackermann, chief, State Water Survey Division, Urbana, Ill., reported a reduction in evaporation of 43 and 22 percent during the summers of 1957 and 1958 from small lakes in central Illinois.

Destruction of the compressed monolayer film by wind and wave action and biological attrition are the most serious obstacles that must be overcome. Continuing research on other monolayer-forming chemicals and in methods of application will undoubtedly solve these problems. It is quite possible that by the year 2000 the evaporation from some lakes and reservoirs will be reduced by 25 percent, although this possible reduction was not considered on the structures shown in table 5.

Ground water.—In nearly all areas where ground water is now being used extensively, water is being taken from storage, and recharge is not keeping pace with discharge. Demand for water is increasing in most areas. If these conditions persist, some ground-water supplies (except those valley aquifers being recharged directly from flowing streams in the valley) will have been depleted or rendered uneconomical by the year 2000. Lowering ground-water levels permits the encroachment of sea water or poor quality water into some aquifers—which, if left unchecked, may destroy their usefulness forever. Research may reveal more efficient means of recharging ground-water supplies. New exploration tools may reveal undiscovered sources of ground water, and demineralization processes may permit the use of low-quality ground water.

Although the effect of such developments could influence the estimates presented in the report, they were not considered, in view of their uncertainty.

Use of saline waters.—Extensive research is now being conducted on the demineralization of saline waters, especially sea water. When costs are lowered to the point where demineralization processes are competitive with other means of water development, the demand for present supplies of surface and ground water may be reduced in certain downstream areas. Direct substitution of demineralized water for ground water in downstream and coastal areas may relieve the problem of depletion and/or salt water encroachment. The demineralization of presently unusable supplies of ground water will also supplement supplies of both surface and usable ground water. However, these possibilities have not been included in any estimates presented in this report.

Watershed management.—There may be some additional watershed management measures installed on certain areas of land in the West in an effort to increase water yield. Measures of this type are discussed in the Department's report in reply to the letter of July 13, 1959, from the U.S. Senate Select Committee on National Water Resources. Although research results indicate that such measures could produce increases in water yield, not enough knowledge is presently available to estimate the effects upon major water resource regions. Therefore no increase in water yields resulting from such watershed management measures has been included in the estimates contained in this report.

The control of riparian vegetation offers some possibility for increasing downstream yields. This has been considered to the extent that increased efficiency has been assumed in the transmission of irrigation water. Since this report considers yields from drainage areas of only 1,000 square miles, no further increase in yield has been considered for the control of riparian vegetation in downstream areas.

[6] Committee Print No. 12.

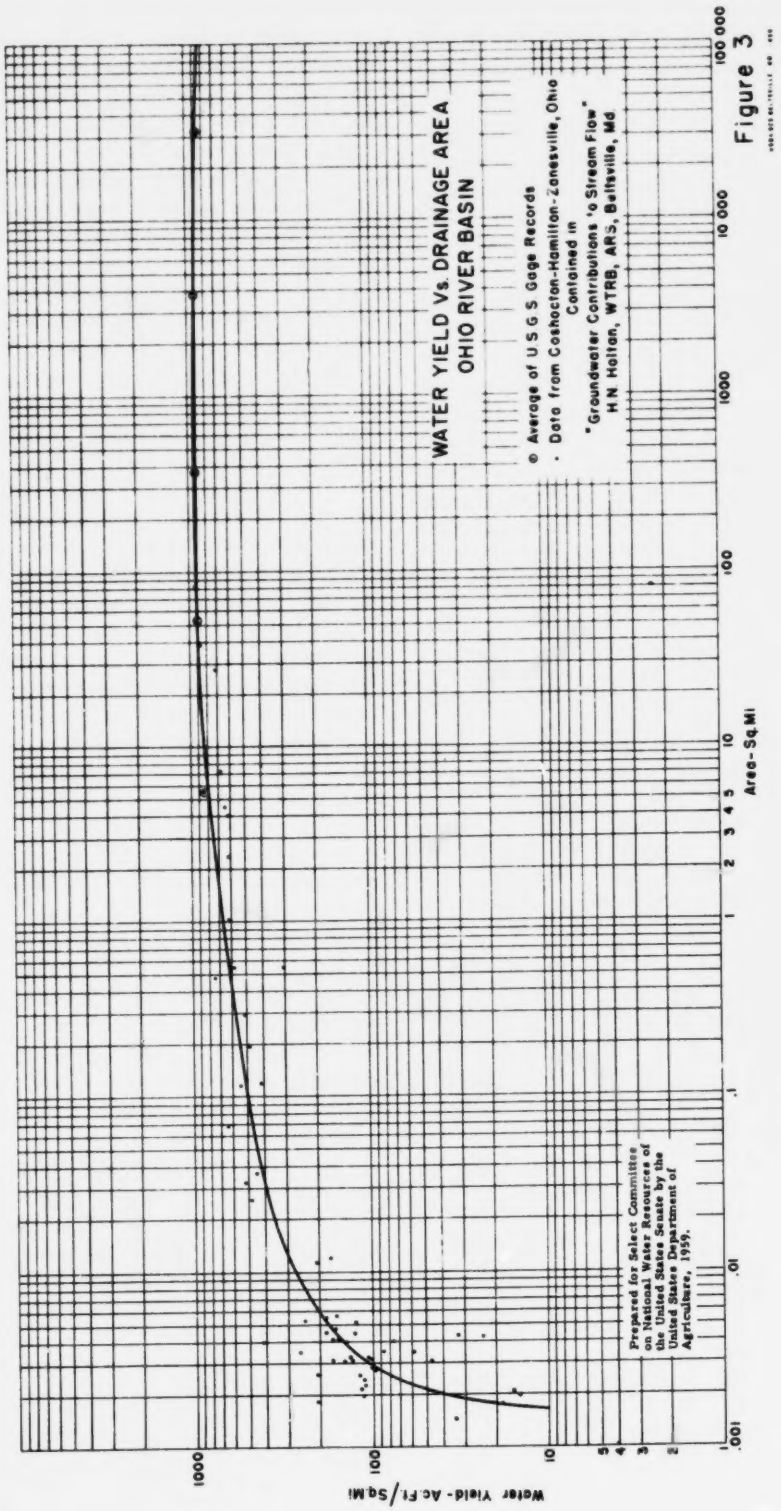

WATER YIELD Vs. DRAINAGE AREA
OHIO RIVER BASIN
© Average of U S G S Gage Records
· Data from Coshocton-Hamilton-Zanesville, Ohio
Contained in
"Groundwater Contributions to Stream Flow"
H N Holtan, WTRB, ARS, Beltsville, Md
Prepared for Select Committee on National Water Resources of the United States Senate by the United States Department of Agriculture, 1959.
Water Yield - Ac Ft/Sq Mi
Area - Sq Mi
1000
100
10
5
4
3
2
1
.001
.01
.1
1
2
3
4
5
10
100
1000
10 000
100 000

Figure 3

A

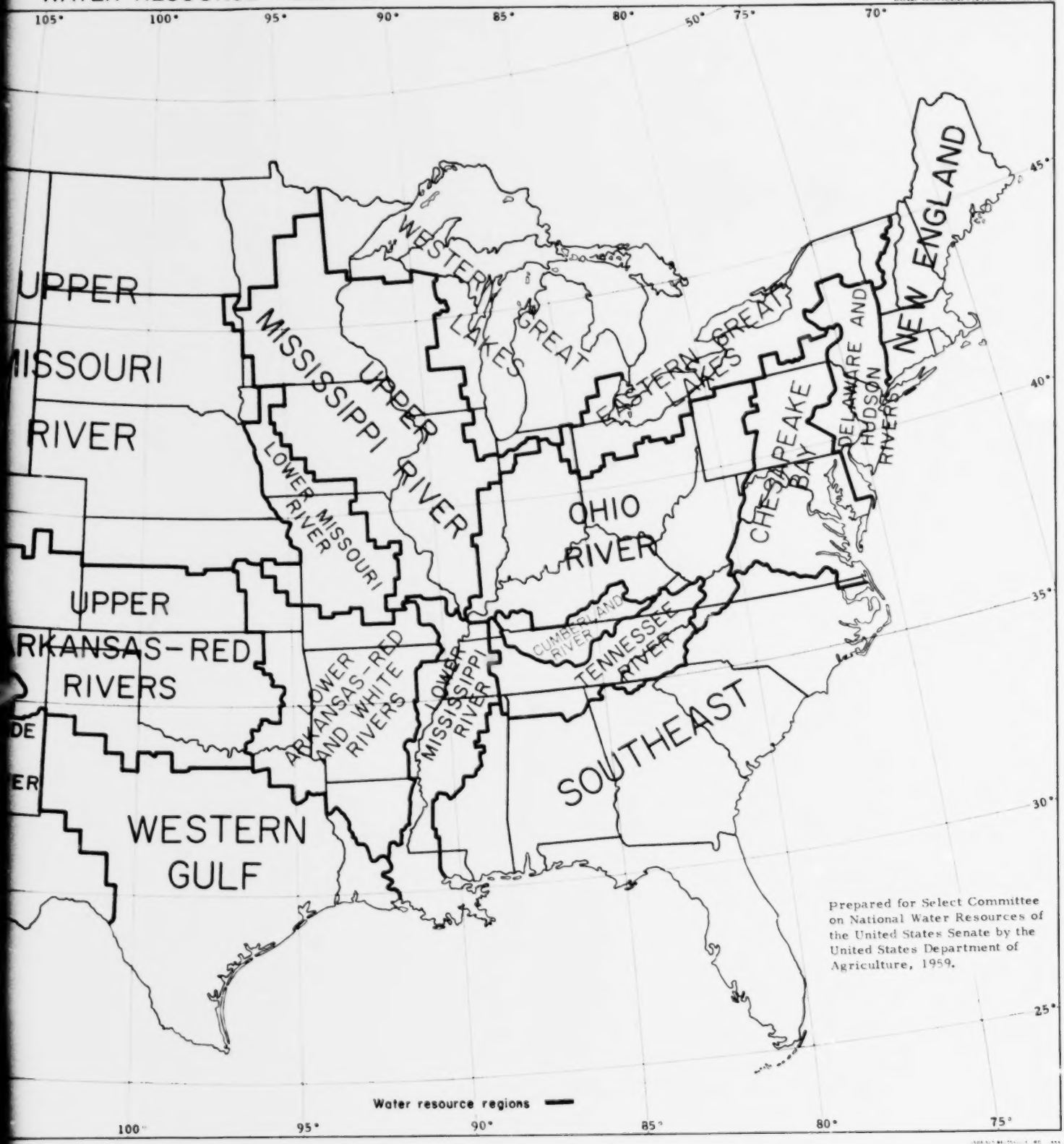
UNITED STATES DEPARTMENT OF AGRICULTURE

WATER RESOURCE REGIONS

WATER RESOURCE REGIONS

B

SOIL CONSERVATION SERVICE



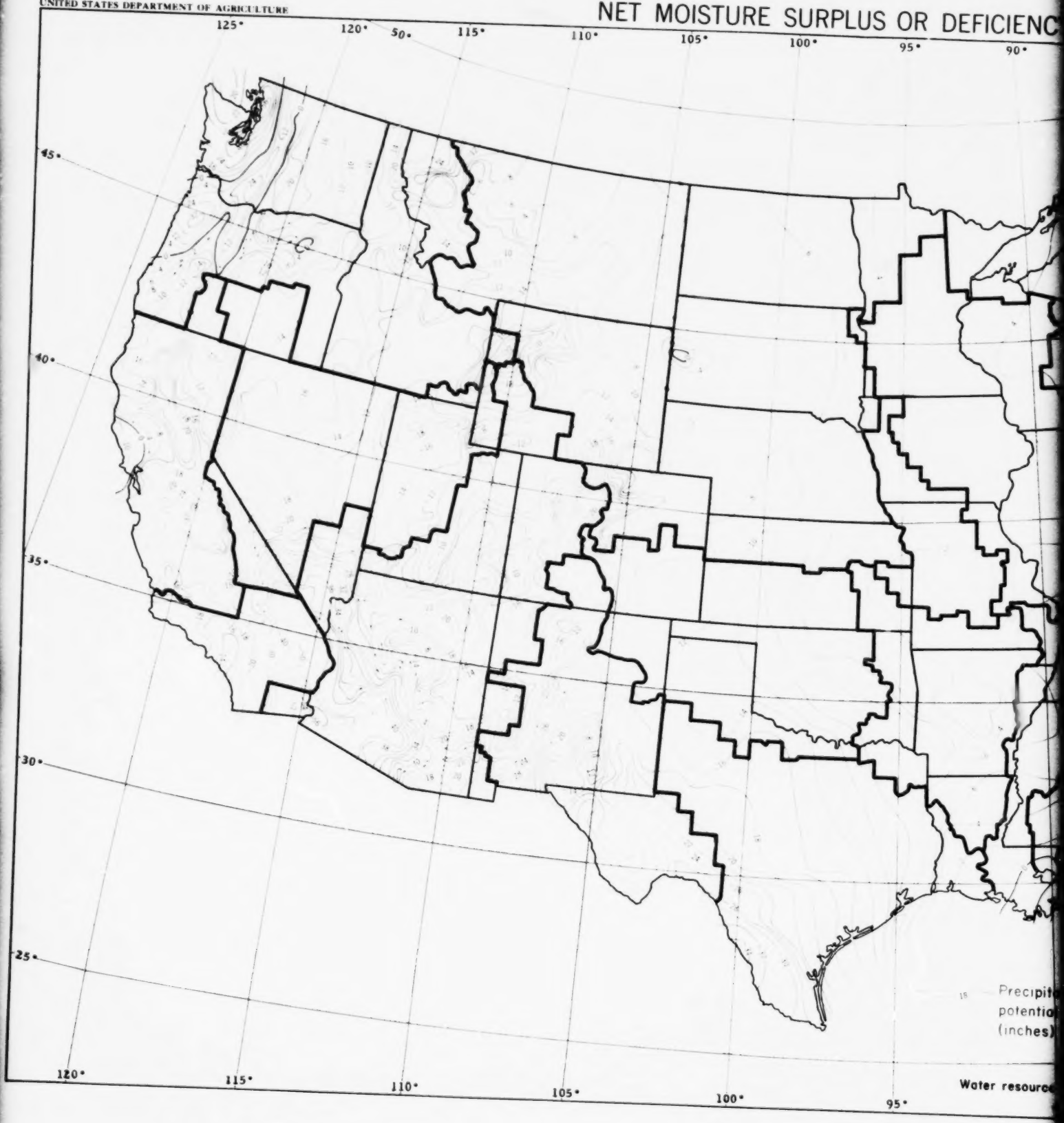
Prepared for Select Committee on National Water Resources of the United States Senate by the United States Department of Agriculture, 1959.

Figure 1

A

UNITED STATES DEPARTMENT OF AGRICULTURE

NET MOISTURE SURPLUS OR DEFICIENC



MOISTURE SURPLUS OR DEFICIENCY

SOIL CONSERVATION SERVICE

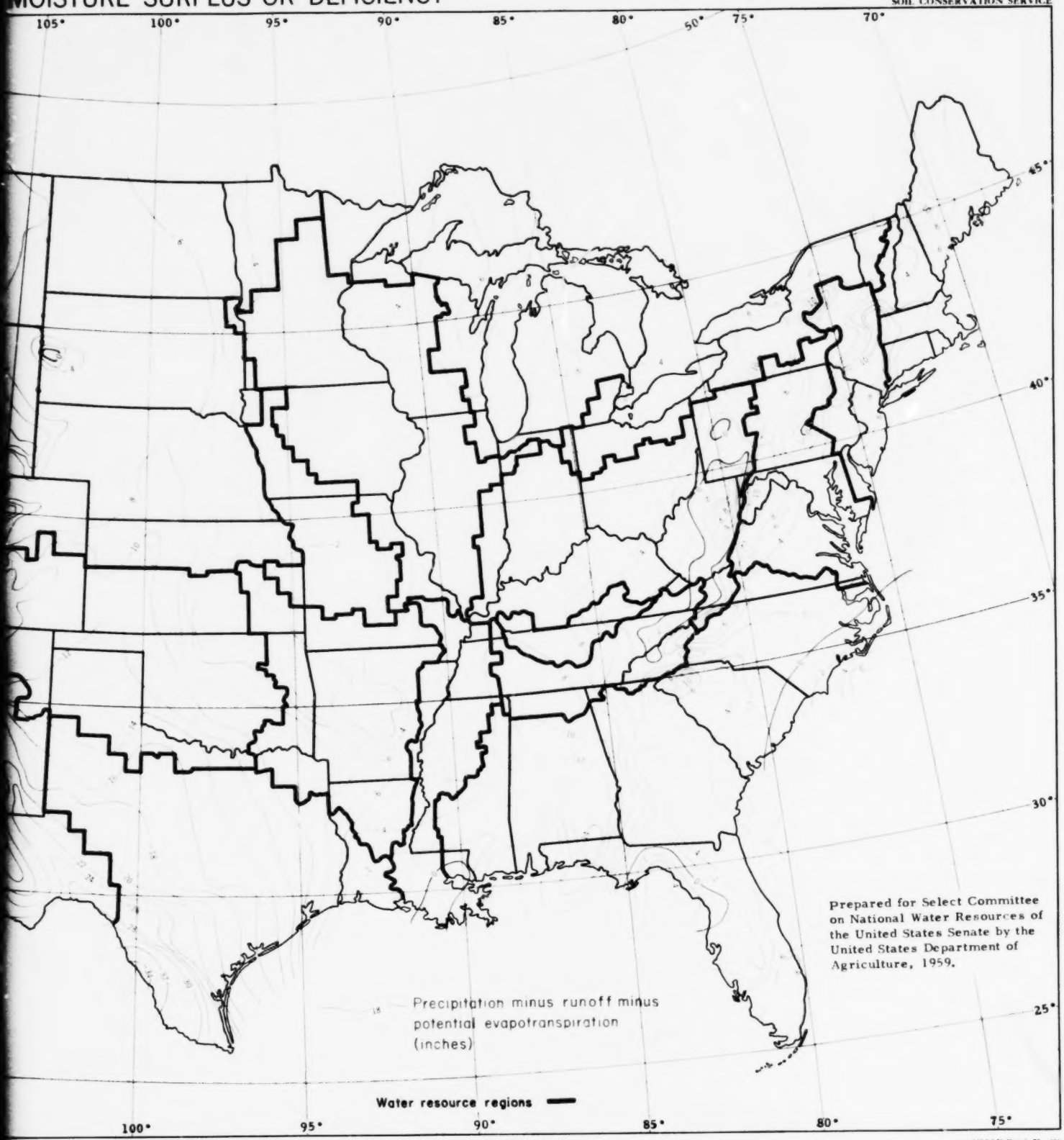


Figure 4

A

UNITED STATES DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL POTENTIAL EVAPOTRANS

Reference:

Physical Basis of Water Supply and It's Principle Uses, Interior and Insular Affairs Committee, House of Representatives, United States Congress, 1952. Figure 28. Evapotranspiration in the Hydrologic Cycle, C. W. Thornethwaite.

B

ANNUAL POTENTIAL EVAPOTRANSPIRATION

SOIL CONSERVATION SERVICE

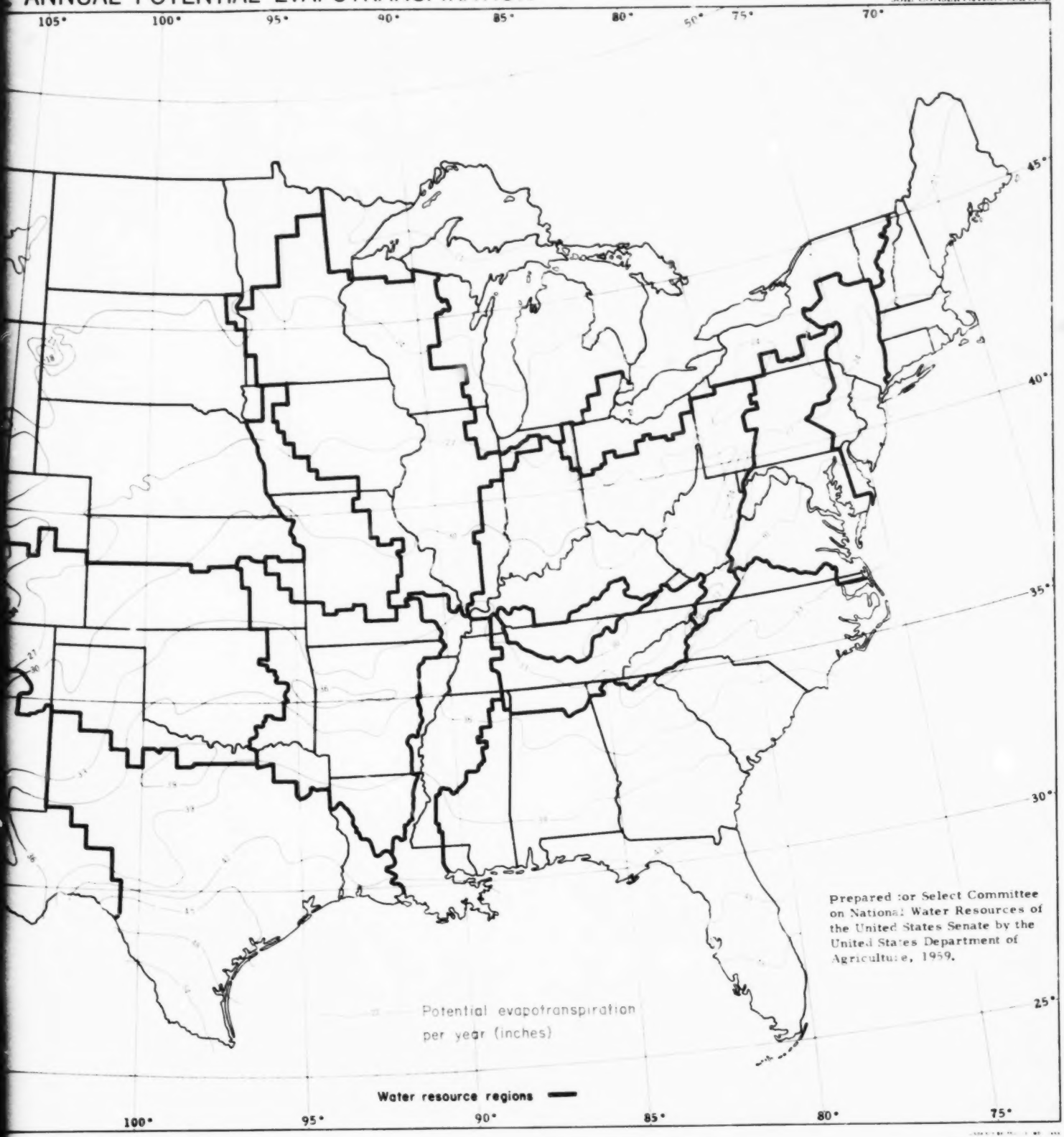
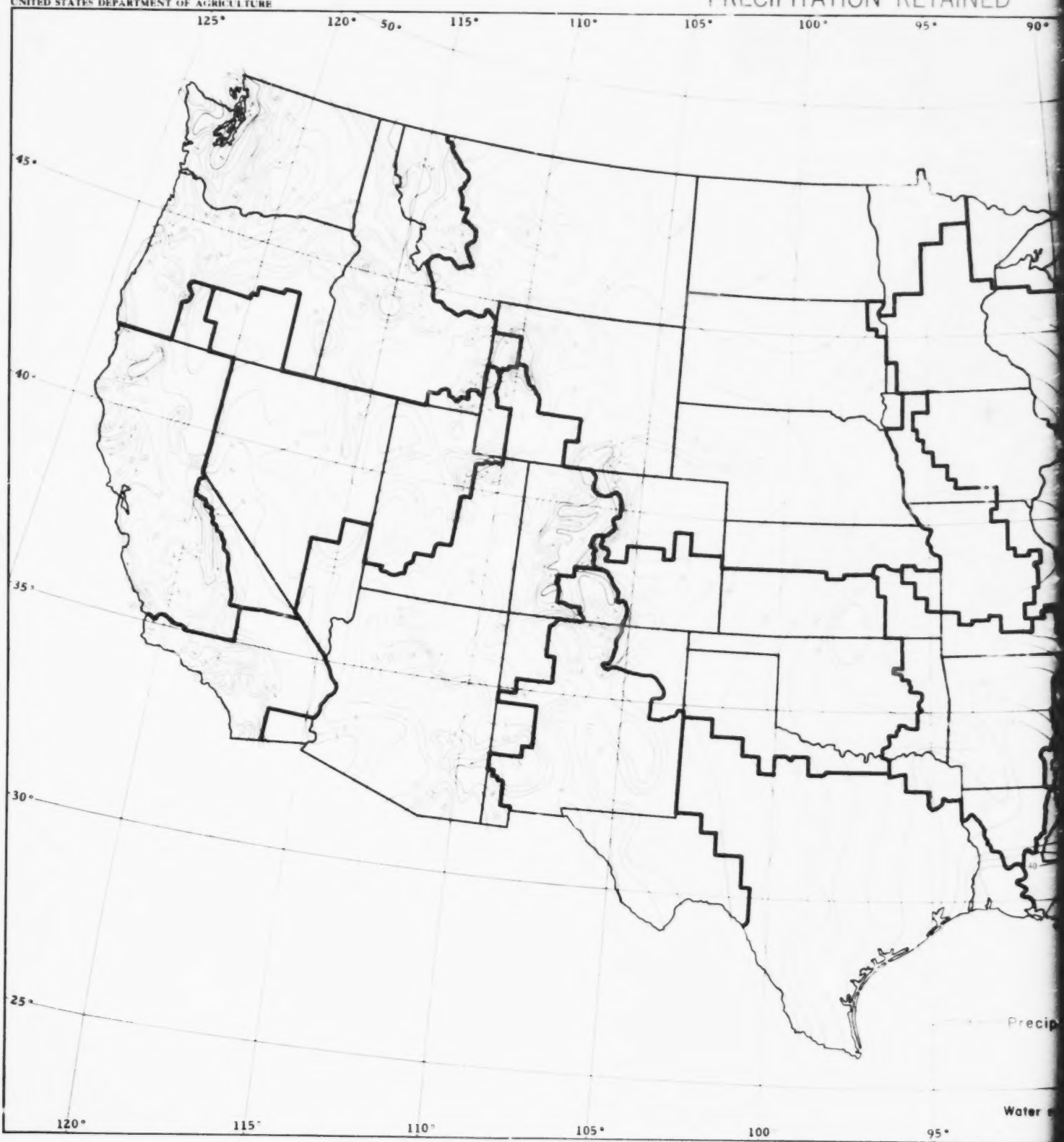


Figure 5

A

UNITED STATES DEPARTMENT OF AGRICULTURE

PRECIPITATION RETAINED



PRECIPITATION RETAINED

B

SOIL CONSERVATION SERVICE

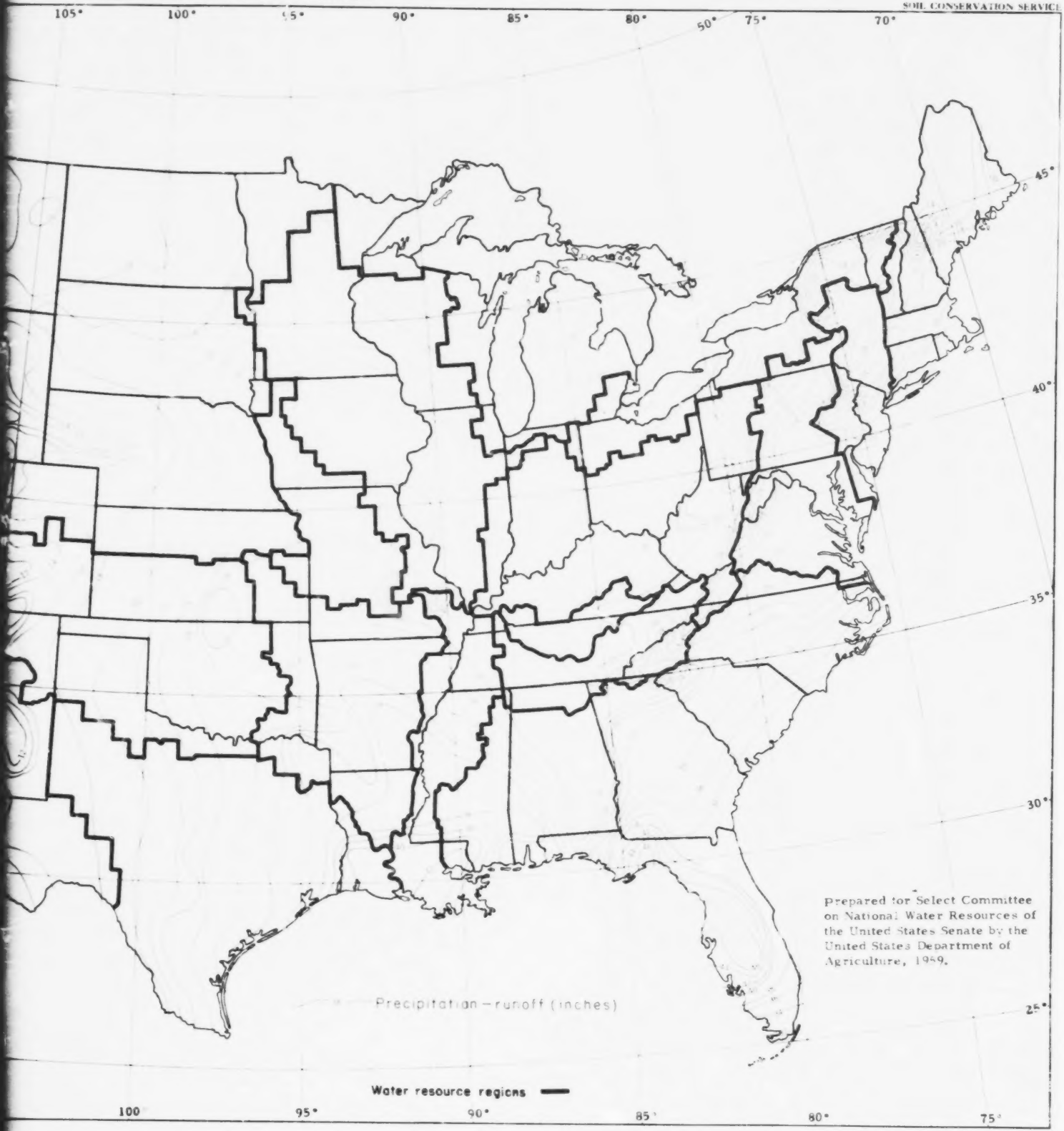
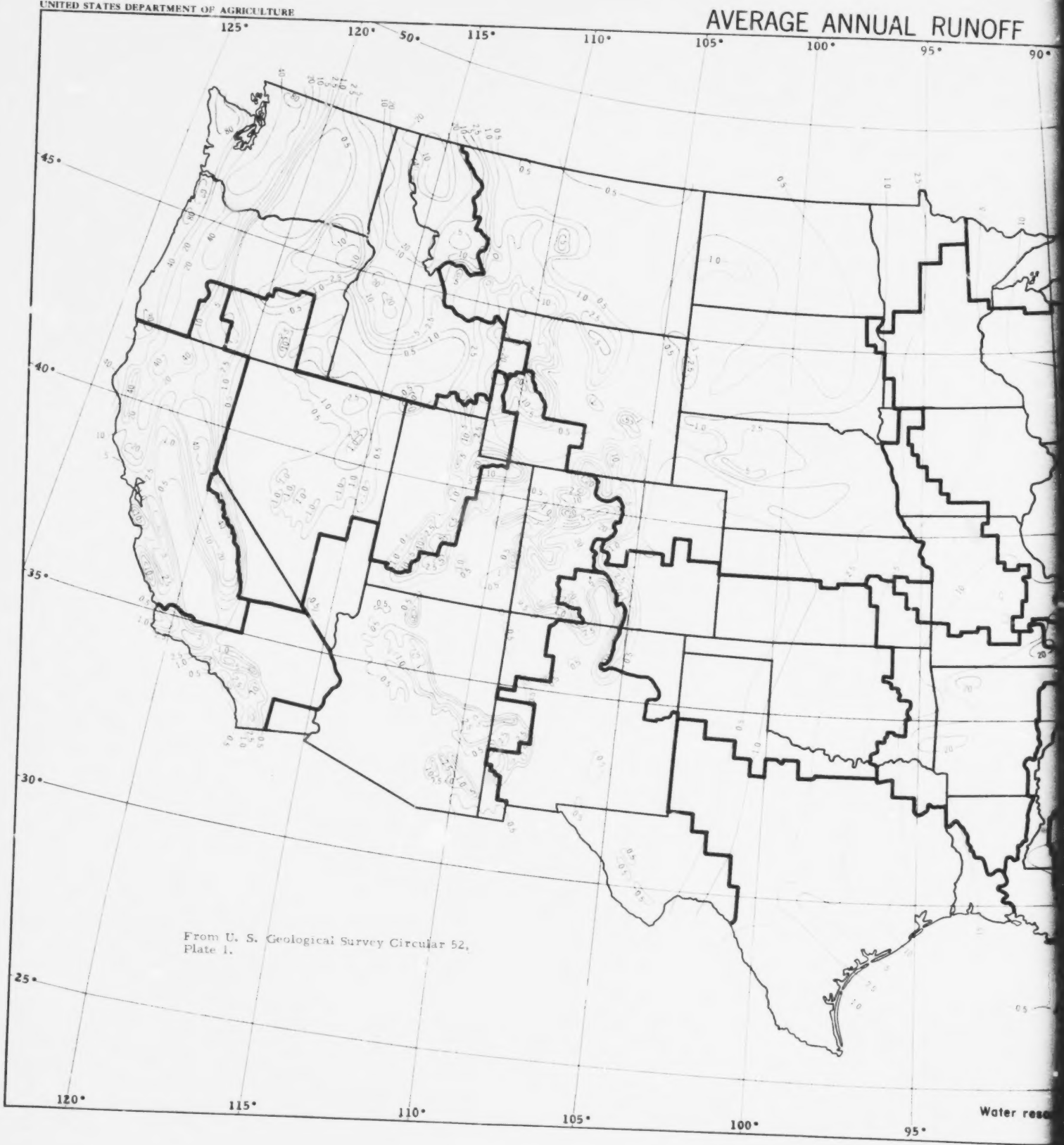


Figure 6

A

UNITED STATES DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL RUNOFF



From U. S. Geological Survey Circular 52, Plate 1.

Water reso

AVERAGE ANNUAL RUNOFF

B

SOIL CONSERVATION SERVICE

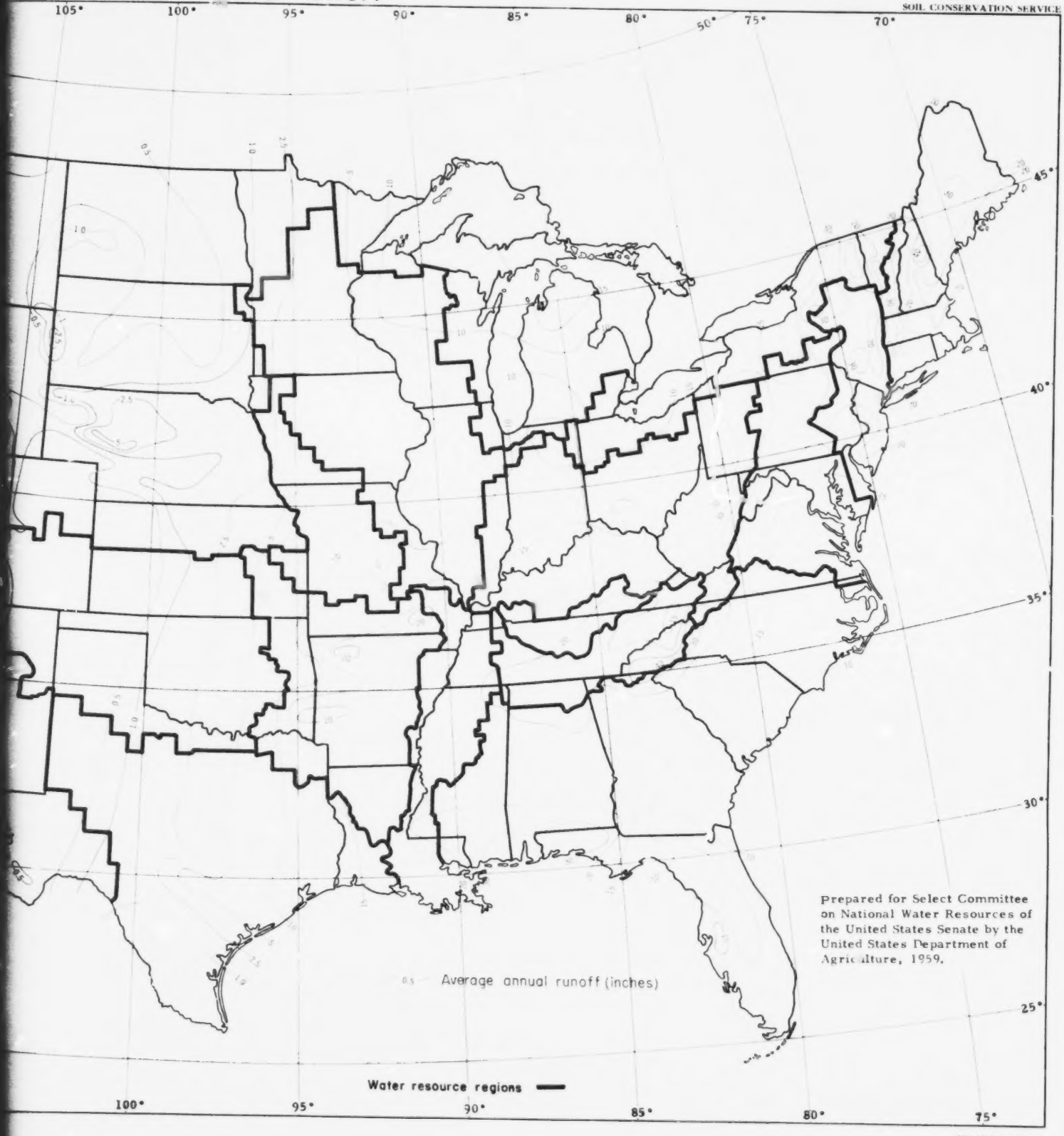


Figure 7

A

UNITED STATES DEPARTMENT OF AGRICULTURE

NORMAL ANNUAL AMOUNT OF PRECIP

B

MAL ANNUAL AMOUNT OF PRECIPITATION

SOIL CONSERVATION SERVICE

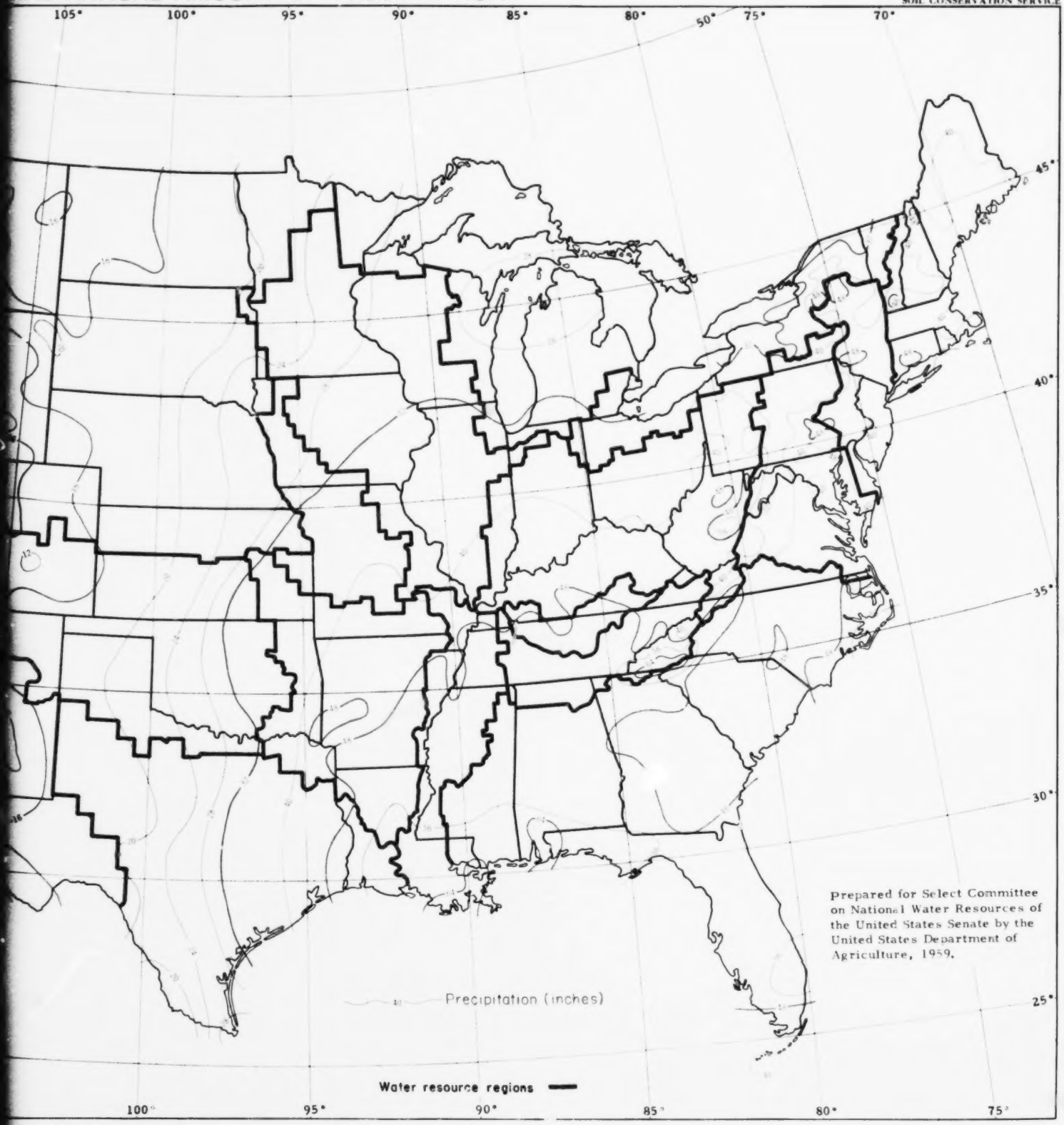


Figure 8

A

UNITED STATES DEPARTMENT OF AGRICULTURE

NET LOSS FROM PONDS AND RESERV

LOSS FROM PONDS AND RESERVOIRS

SOIL CONSERVATION SERVICE

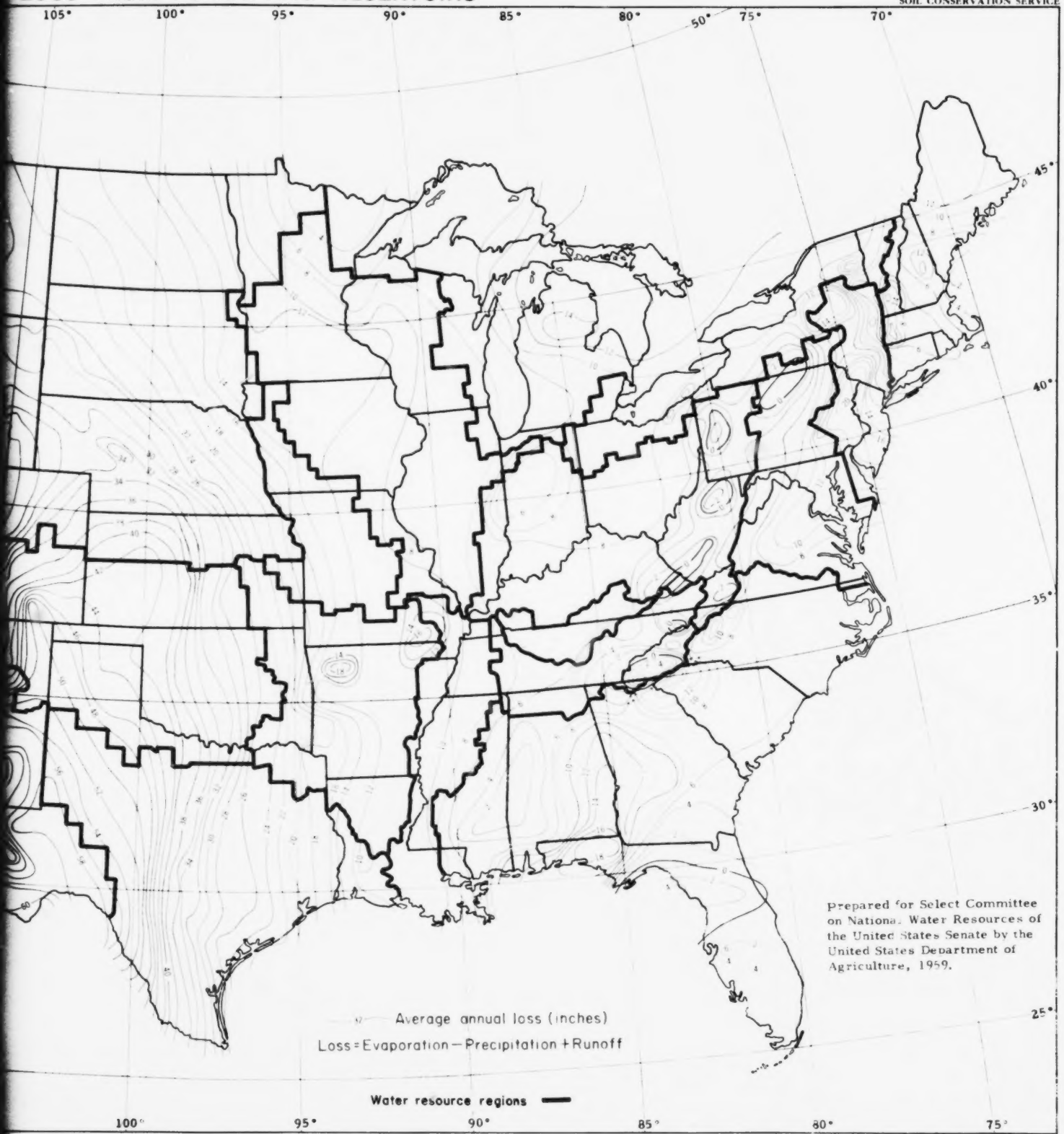


Figure 9

A

UNITED STATES DEPARTMENT OF AGRICULTURE

NET EVAPORATION FROM PONDS AND RESER

APORATION FROM PONDS AND RESERVOIRS

B

SOIL CONSERVATION SERVICE

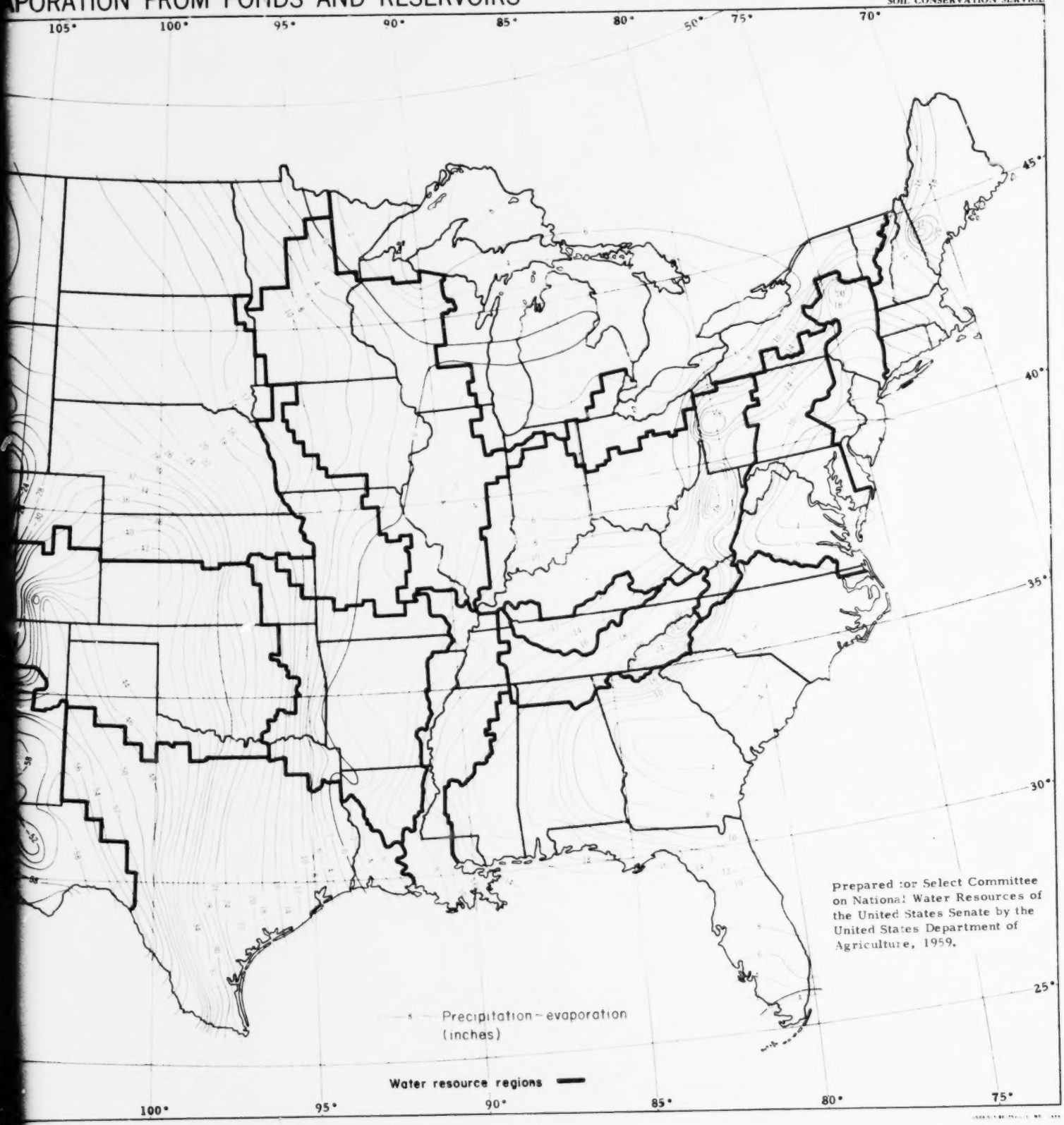


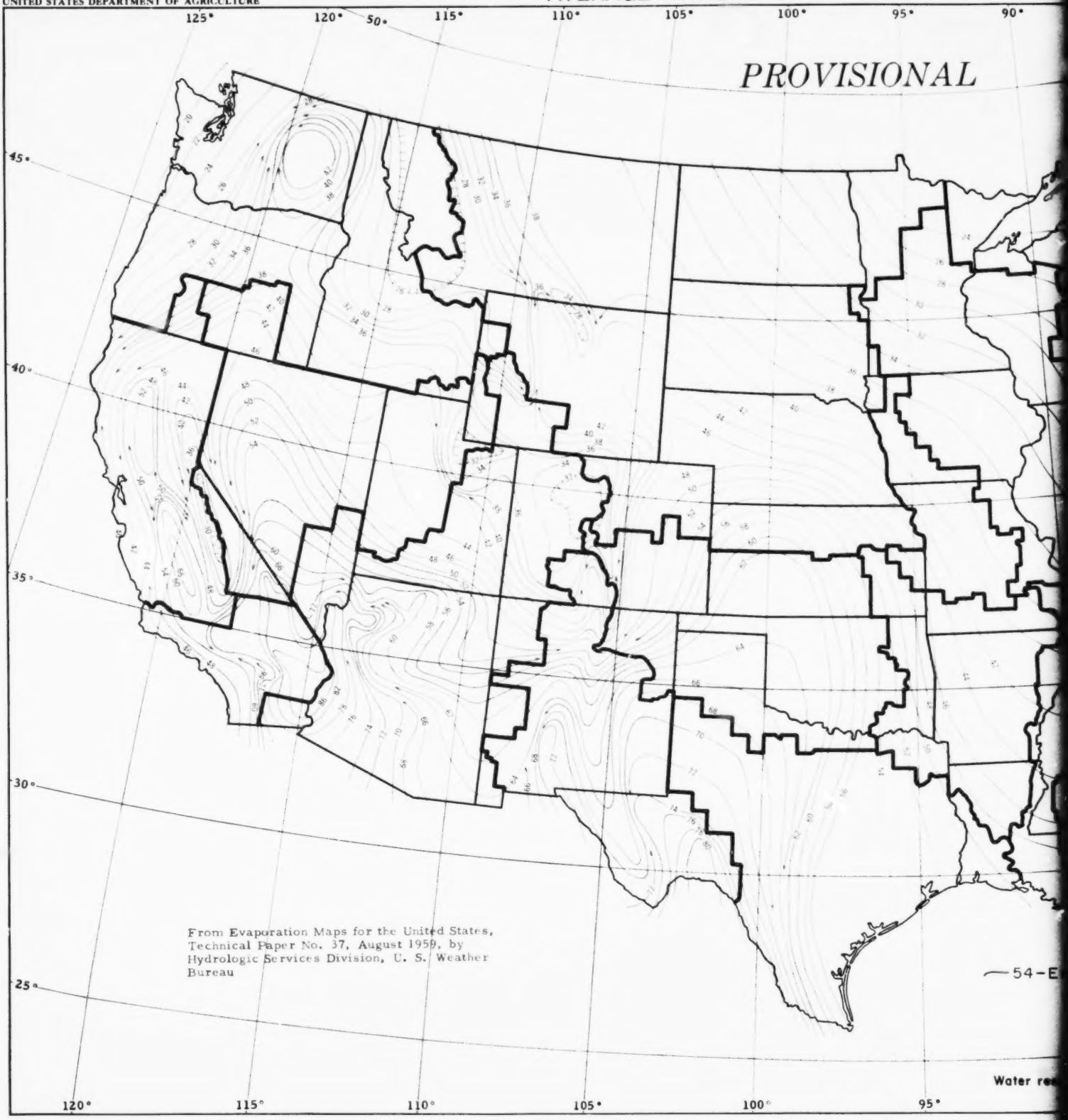
Figure 10

A

UNITED STATES DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL LAKE EVAPORATION (194

PROVISIONAL



From Evaporation Maps for the United States, Technical Paper No. 37, August 1959, by Hydrologic Services Division, U. S. Weather Bureau

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Water re

ANNUAL LAKE EVAPORATION (1946-1955)

SOIL CONSERVATION SERVICE

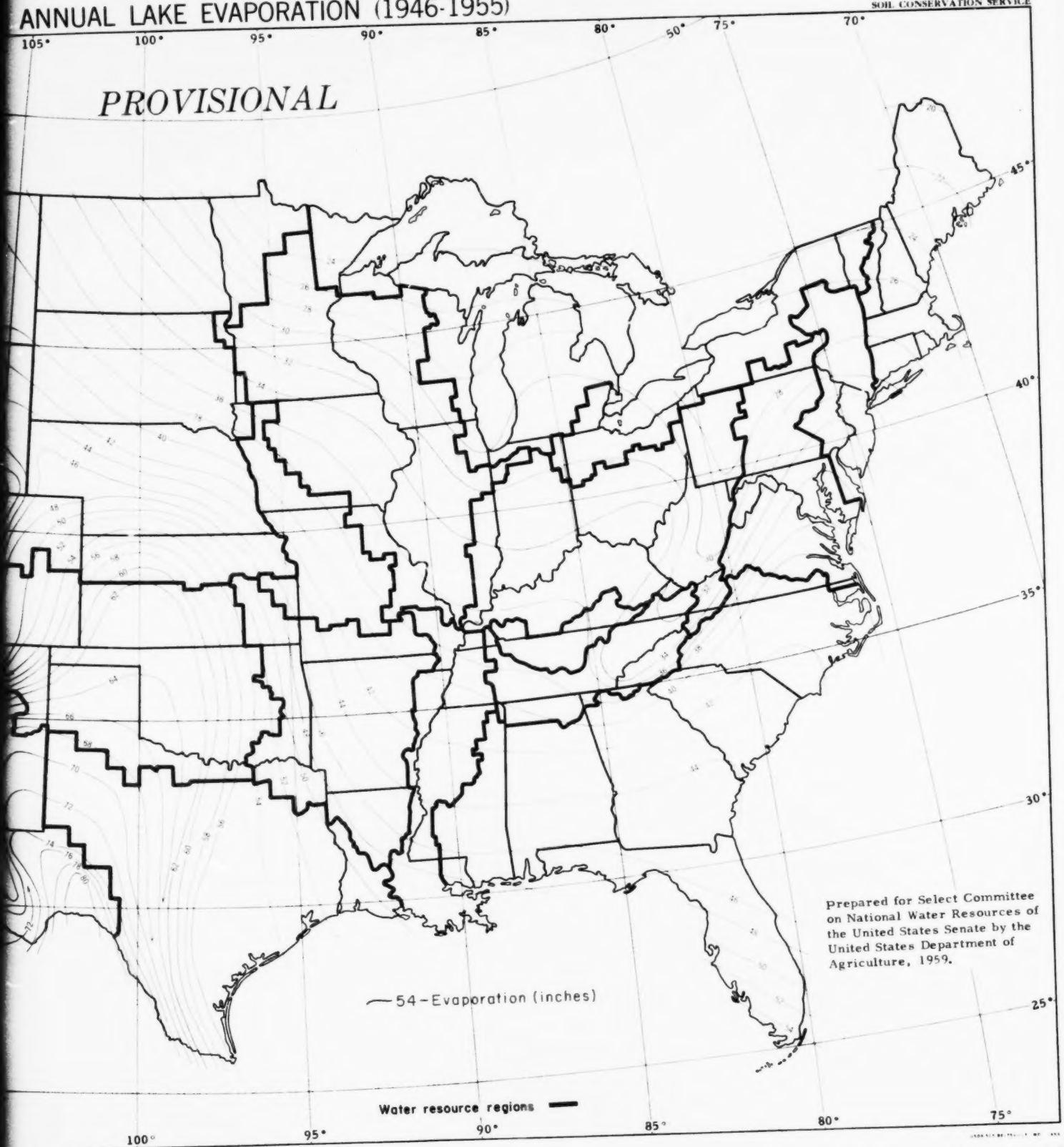


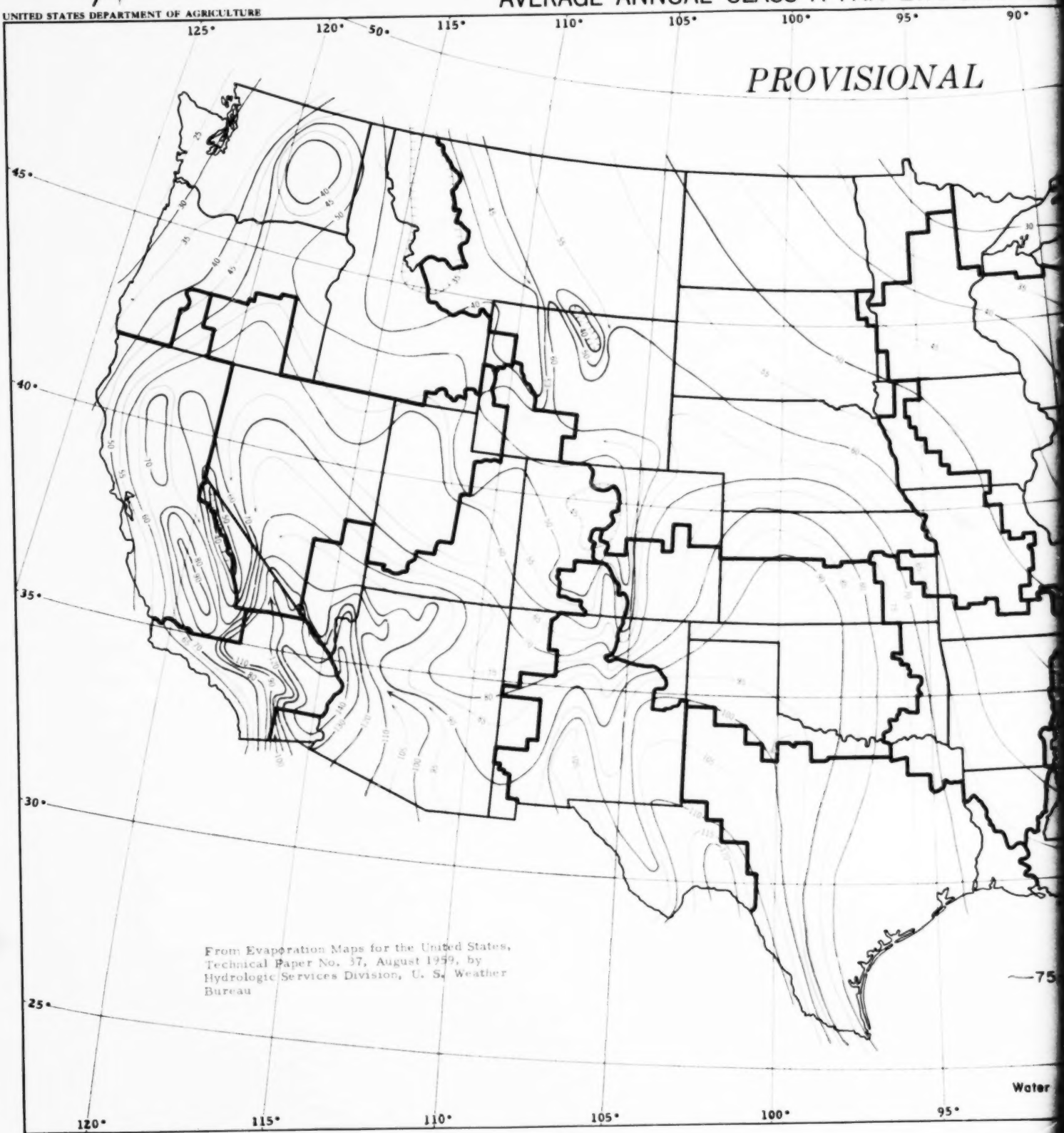
Figure 11

A

UNITED STATES DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL CLASS A PAN EVAPORATION

PROVISIONAL



From Evaporation Maps for the United States, Technical Paper No. 37, August 1959, by Hydrologic Services Division, U. S. Weather Bureau

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ANNUAL CLASS A PAN EVAPORATION (1946-1955)

SOIL CONSERVATION SERVICE

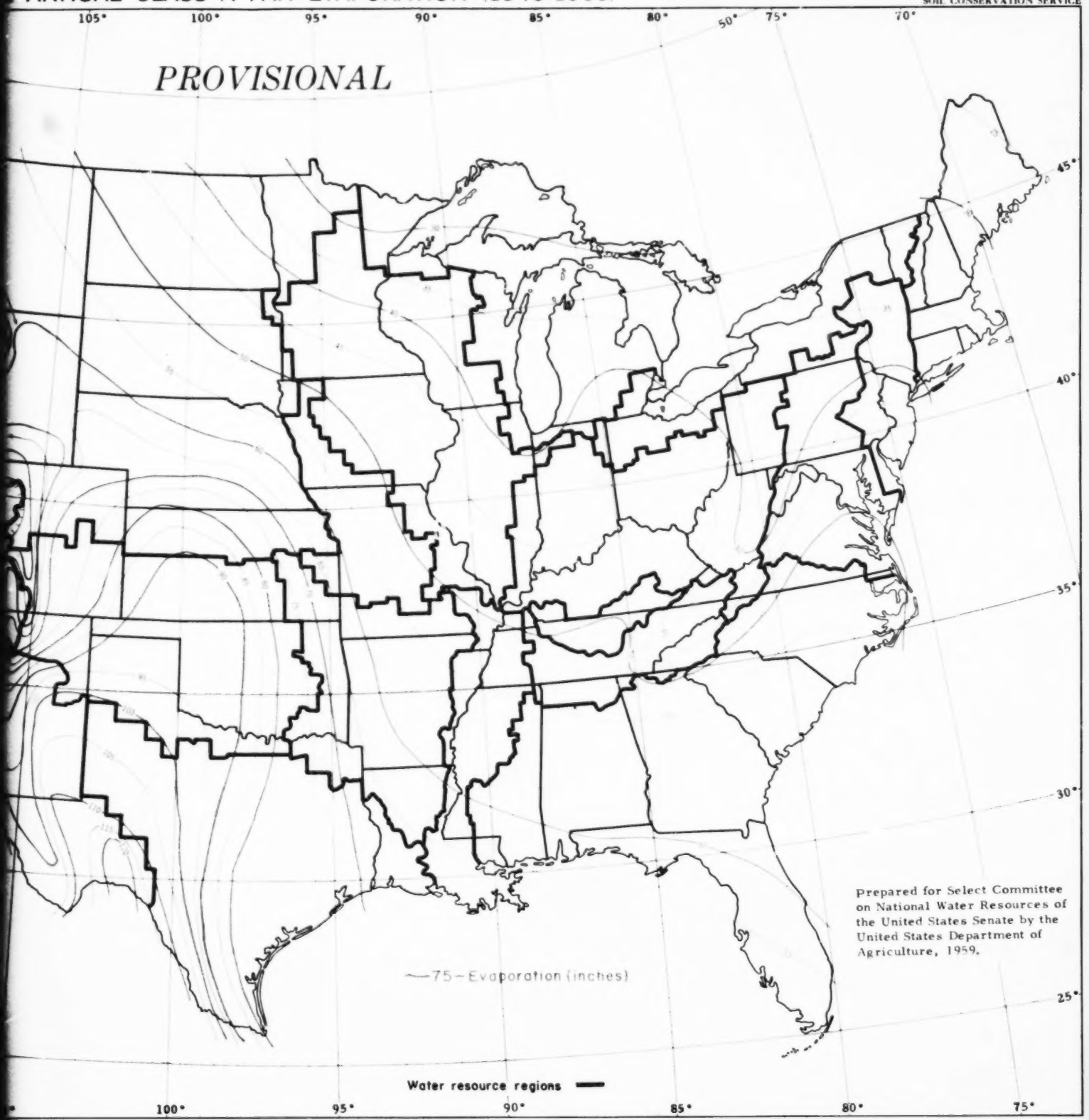

Figure 12

A

UNITED STATES DEPARTMENT OF AGRICULTURE

AVERAGE ANNUAL CLASS A PAN COEFF

RAGE ANNUAL CLASS A PAN COEFFICIENTS

SOIL CONSERVATION SERVICE

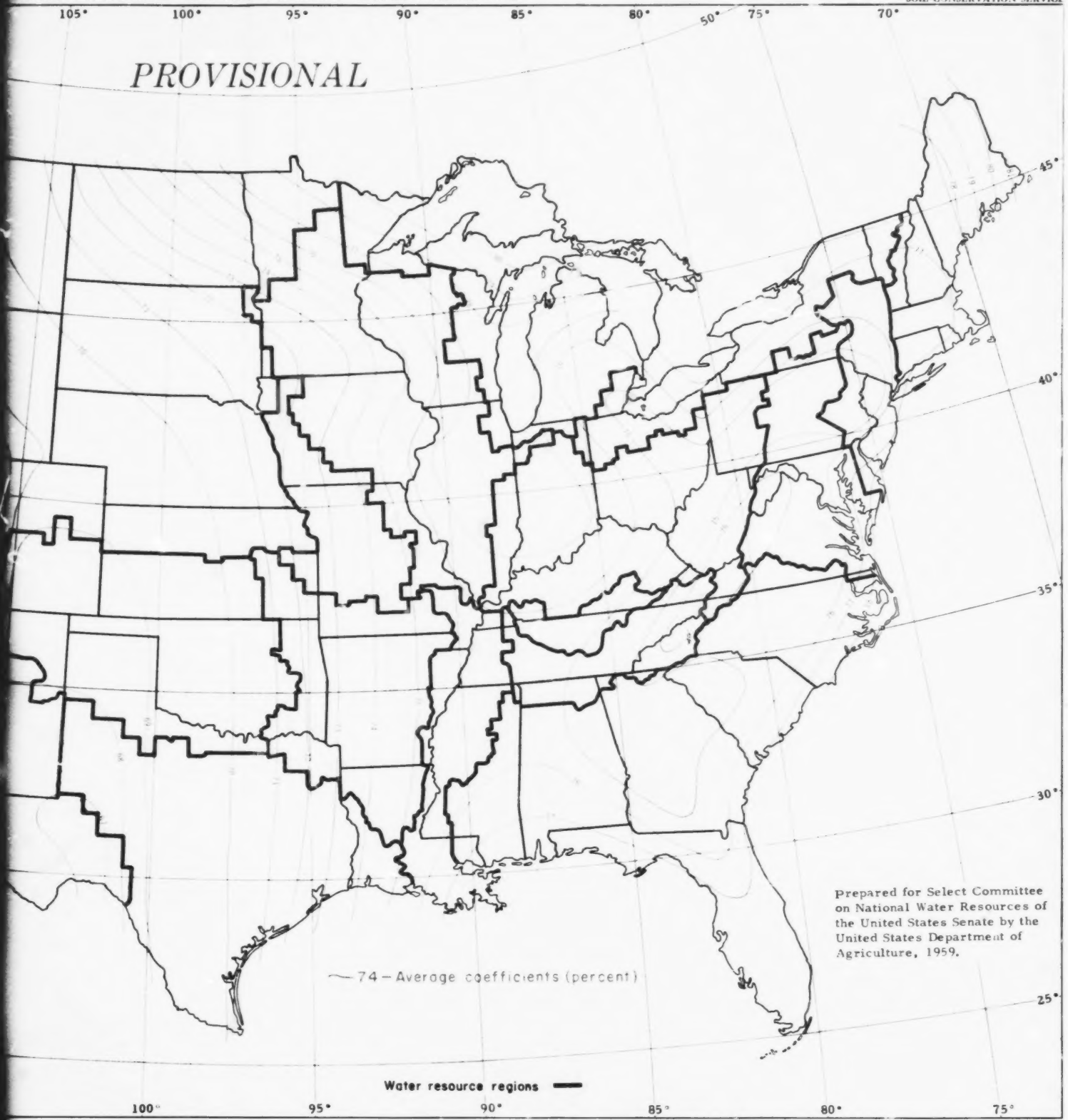

Figure 13